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WELSH PLANT BREEDING STATION.

Seeds Mixture Problems: Competition

by

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PREFATORY NOTE.

When breeding work with herbage plants was started at the Station it at once became apparent that the geneticist was possessed of practically no reliable information as to the precise characteristics which constitute "desirable attributes" in the material at his disposal. At the outset, therefore, it was decided to plan an exhaustive series of seeds mixture experiments, designed as far as possible to ascertain the factors which influence sward establishment on the one hand, and progressive changes in the sward on the other, and to study the matter from the point of view of individual species.

As the work proceeded, it became evident that the master factor dominating all influences affecting swards is to be regarded as the competitive interaction of the species in sympathy with changes in the intensity of operation of the various factors of environment.

The investigations were started by working with pure species and ascertaining the factors influencing soil establishment; subsequently the species were sown in mixtures, and the factor of competition was made the chief object of study. The present bulletin is concerned wholly with trials in the latter category, the results of the "pure species" trials having been previously reported.

The experiments now under review fall into two divisions: firstly, those of a preliminary nature designed to explore the scope of the phenomena under study; and secondly, more critical trials planned to investigate certain definite and explicit reactions of the several species in sympathy with contrasting methods of management.

The two classes of trials are dealt with in separate papers, while the bulletin includes a third paper in which the evidence as a whole is brought to bear on the important economic question of compounding seeds mixtures.

The data presented in this bulletin cover investigations started in 1921 and carried to the Spring of 1928—a large number of the experiments being still in progress.

The various trials brought under review have entailed the setting up of 2,819 separate plots (the size has varied from less than 1 yard square in the case of garden experiments to field plots of $\frac{1}{4}$ acre)—the majority of the plots have been 1/400th, 1/200th or 1/100th of an acre. For the purpose of dry weight estimates and of botanical analyses (including separation into the component species; separations into stem and leaf, and into stem shoots and leaf shoots) approximately 5,000 samples of green herbage cut from the plots have been taken, of which number 3,390 have been used for botanical separations. In connection with the ground analyses on the plots *in situ* over 9,000 readings have been made with a mesh 6 inches by 6 inches, while 3,700 turfs (6 inches by 6 inches) have been lifted for critical analyses in the laboratories.

It has only been possible to conduct a programme of investigation such as this by the judicious employment of a large number of well-trained technical assistants. To carry such a programme to a successful issue, therefore, depends to a marked degree upon the general organization and training of the human resources at the disposal of the investigator. The team of workers concerned

with the conduct of the majority of these trials have been under the general direction of Mr. Wm. Davies, who for the last four years has supervised and planned the whole scheme of work. The team has consisted of from two to six student-assistants and from four to twelve technical (laboratory) assistants (Station-trained young women and girls). The student-assistants have been chiefly responsible for analyses made *in situ* on the plots and for those made on lifted turfs. The technical assistants have in the main conducted the laborious separations made in the laboratory on the cut herbage. In addition much of the sampling has been done by selected "farm hands" specially trained to critical work of this sort; selected men similarly taking a prominent part in the sowing and weighing of the plots. During the growing season two men have always been at Mr. Davies's disposal for the purpose of sampling. The sowing of the plots is a very important matter. The names of the sowers are recorded on the plans for the several experiments, and during the earlier years, prizes were given to the men showing the greatest skill. Three men have proved to be of outstanding merit, and these are now always employed for the sowing of the smallest plots connected with the most critical work.

The investigations here reported upon have been rendered possible just because a team of workers varying in number from about 8 to 20 have been made available for this one line of study as and when required during a period extending over six years. At no time during 1926 and 1927, week in and week out throughout the year, was the number of workers engaged upon these trials less than eight.

The very nature of herbage problems is such that the underlying facts can only be elucidated by the conduct of very large numbers of time-taking and laborious analyses, and on this account it has seemed desirable to give some indication of the means which have been adopted with a view to solving the most difficult of all herbage problems, namely, how to have a sufficiently large number of analyses and separations accurately conducted. It is thought that workers on similar lines will be interested to have an approximate idea of what was involved in terms of human energy relative to the accumulation of the data contributing to this bulletin.

Thanks are due to Captain R. D. Williams, M.Sc., who was largely responsible for the conduct of some of the earlier trials and to whom so much is due for the evolution of the field technique now adopted at the Station. Mr. A. R. Beddows, B.Sc., and Mr. W. E. J. Milton, N.D.A., have afforded valuable assistance in connection with a number of the trials, and to both thanks are due. Thanks are similarly due to Mr. J. W. Watkins, Superintendent of the Farm and Gardens for invaluable supervision in connection with sowing and harvesting.

The following students of the College (past or present) have taken an active part with reference to the various botanical analyses, to all of whom very special thanks are due :—Mr. D. J. Columbus Jones, B.Sc. (now on the scientific staff of Messrs. Sutton and Sons of Reading); Mr. A. D. Thomas, B.Sc. (now Vice-Principal of Pibwrlwyd Farm Institute, Carmarthenshire); Mr. J. G. Davies, Ph.D. (now on the staff of the Waite Agricultural Research Institute, Adelaide); Mr. Gwilym Evans, B.Sc. (now Assistant Organiser for Merionethshire); Mr. J. L. Rees, N.D.A.; Mr. I. G. Lewis, N.D.A.; Mr. Ll. I. Jones, B.Sc., Mr. M. T. Thomas, B.Sc., and Mr. K. Pedersen.

Special thanks are also due to Miss Rhoda Jones, B.A., who has seen this bulletin through the press.

In connection with the county trials it is a pleasure to express gratitude for the unfailing assistance of the County Organizers, namely :—Mr. Dd. Thomas of Brecon and Radnor ; Mr. D. J. Morgan, B.Sc., of Cardiganshire ; Principal J. L. Lloyd, M.Sc., of Carmarthenshire ; Mr. Moses Griffith, M.Sc., of Merionethshire ; Mr. J. L. John, B.Sc., of Montgomeryshire, and Mr. W. E. D. Jones, M.A., of Pembrokeshire.

In conclusion it is desired to place on record the Station's indebtedness to those landowners and farmers who have afforded facilities on their farms for the conduct of the county trials. In connection with the investigations under review, thanks are particularly due to the Rt. Hon. the Earl of Lisburne, of Crosswood, and to Messrs. Hugh Jones (Pensarn, Talybont) ; T. Jones (Moelglomen, Talybont) ; J. M. Edwards (Nantsiriol, Bow Street) ; J. W. Davies (Penybank, Llangybi) ; and J. I. Williams (Pengraig, Llanfarian).

Messrs. Sutton and Sons of Reading kindly presented and prepared (weighed out for the plots) all the seed for one of the more extensive trials, and for this invaluable assistance grateful acknowledgment is made.

R. G. STAPLEDON.

AGRICULTURAL BUILDINGS,
ABERYSTWYTH,
September, 1928.

SEEDS MIXTURE EXPERIMENTS WITH SPECIAL REFERENCE TO THE INFLUENCE OF ENVIRONMENTAL FACTORS.

BY

R. G. STAPLEDON, M.A., AND WM. DAVIES, M.Sc.

E. 19: SEEDS MIXTURE EXPERIMENT: PENGLAIS FIELD: SOWN 1921.

This experiment was primarily designed to test the effect of one species upon another in seeds mixtures. Ordinary commercial seed was used in all cases, since no pedigree indigenous strains were available when the trial was set up—commercial wild white clover being the only indigenous seed sown.

THE FIELD: PREVIOUS CROPPING.—The Penglais Field had been in permanent grass for a large number of years previous to 1918 when it was ploughed under the war-time food production orders and sown in oats. The portion of the field subsequently devoted to E. 19 grew a crop of rape and red clover in 1919 following the oats, and in 1920 the area was utilized for oat variety trials. The seeds mixture experiment was sown in August, 1921, when the area received high-grade basic slag at the rate of 5 cwt. per acre, the only manure applied either before or during the period of the experiment.

The field slopes from east to west, the soil being a loam rather shallow towards the top and deep and rich towards the bottom.

The whole field had been largely dominated by bent in the original sward—*Agrostis vulgaris* being most plentiful towards the top and *A. stolonifera* being at least equally plentiful towards the bottom; Yorkshire fog was also very abundant.

The field has not once been subjected to proper cleaning operations subsequent to breaking the original sward and up to the time of sowing the experimental mixtures, for although it was fallowed during the spring and summer of 1921, the Station was then largely dependent on hired horse labour, and the operations were consequently not sufficiently well carried out. The experiment was, therefore, put down under conditions rather similar to those under which so much land was hurried down to grass after the war. The bent had never been properly killed, and from the outset the sown seeds had to compete with excessive bent and fog development, with the result that by the second harvest year unsown species on most of the plots were contributing over 20 per cent. to the total herbage, while by the fourth harvest year the sward was to all intents and purposes again completely dominated by bent and fog.

SOWING AND SUBSEQUENT TREATMENT.

Owing to the effect of the drought in 1921 the seeds mixtures were not sown until August 9th. Subsequent critical work at the Station (21)* has shown that this date is usually too late to sow herbage seeds in West Wales. The " takes,"

* Numbers in brackets refer to Literature cited, p. 161.

owing to the exceptional character of the season, were, however, satisfactory, but nevertheless some of the species had been put to a disadvantage by the late sowing ; this was particularly true of wild white clover except where sown in very large amount. Hay crops were taken in each of the first four harvest years—the crop, however, not always being cut early enough. The aftermaths were grazed, but never sufficiently heavily, and only with sheep.

In the light both of practical experience and of other experiments to be brought under review, the management appertaining to this experiment was bad at every turn. The land was foul with bent and fog, the sowing was too late in the season, and the grazing after the hay harvest was not nearly heavy enough. The evidence from this particular experiment has therefore to be considered in relation to the management to which it was necessarily subjected, and in comparison with other experiments dealt with in this bulletin—all the trials taken together will be found to represent a wide range of systems of management, and will make it possible to draw reliable conclusions as to the influences of these various systems.

The value and chief interest of the present experiment therefore turns on the fact that it was sown and managed under conditions particularly favourable to bent domination : thus the evidence as such does not permit of wide generalizations and must be regarded only as a part of the very complete data that will be presented in this bulletin. In connection with putting land down to grass, as with all problems of crop production, it is, however, the part of research stations to investigate the influences of all types of management—good, bad and indifferent—and not only to specialize in the effects of good management, or of so-called good management, for the precise influence of all factors must be explored where the aim is to add to our store of knowledge bearing upon crop production.

In the case of this particular experiment it must be admitted, however, that the bad management was not intentional, but was rather an outcome of the necessarily limited facilities at the disposal of the Station during the earlier years of its foundation.

The Arrangement of the Experiment.

The experimental unit was the rod plot—each mixture was sown on four separate rod plots. The plots were arranged in four sections—two (*a* and *b*) on the upper and shallower part of the field, and two (*c* and *d*) on the bottom part with deeper soil ; all the mixtures were represented by plots in each section. The four sections, (*a*, *b*, *c* and *d*) were cut for hay in the first and second harvest years, while only one of the lower sections (*c*) was cut in the third and fourth harvest years. The seeds mixtures were sown without a nurse crop, and in each harvest year were " put up " to hay not later than early in February.

The Seeds Mixtures.

As previously explained, the seeds mixtures employed were designed with a view to testing the influence of one species on another, and not with the intention that any single mixture should be " sensible " from the practical and economic point of view. The character of the several mixtures with the symbols attached to each are set out in the following schedule :—

I. Hay Mixtures. (Mixtures in lb. per acre).

A.—*Clovers only.*

(1) Late flowering red clover 15 lb.; (2) alsike 10 lb.; (3) late flowering red clover 7½ lb. and alsike 5 lb.; (4) broad red clover 15 lb.; (5) late flowering red clover 3¾ lb.; broad red clover 3¾ lb. and alsike 5 lb.

B.—*Clovers and rye-grasses only.*

No. of mixture.	Italian rye-grass.	Perennial rye-grass.	Broad red clover.	Late flowering red clover.	Alsike.	Wild white clover.	Total. lb.
B. 1	15	..	6	..	..	0.5	21.5
,, 2	..	15	6	..	..	0.5	21.5
,, 3	15	..	..	6	..	0.5	21.5
,, 4	..	15	..	6	..	0.5	21.5
,, 5	15	..	..	..	4	0.5	19.5
,, 6	..	15	..	..	4	0.5	19.5
,, 7	..	15	..	6	..	..	21.0

C.—*No seeding.* These plots were left from the outset to find their own sward.

D.—*Clovers and cocksfoot only.*

No. of mixture.	Cocksfoot.	Broad red clover.	Late flowering red clover.	Alsike.	Wild white clover.	Total. lb.
D. 1	13.5	..	6	..	..	19.5
,, 2	13.5	..	6	..	0.5	20.0
,, 3	13.5	..	..	4	0.5	18.0
,, 4	13.5	..	3	2	0.5	19.0
,, 5	13.5	6	..	..	..	19.5

E.—*Clovers and tall oat grass only.*

No. of mixture.	Tall oat grass.	Broad red clover.	Late flowering red clover.	Alsike.	Wild white clover.	Total lb.
E. 1	30	..	6	..	..	36.0
,, 2	30	..	6	..	0.5	36.5
,, 3	30	..	..	4	0.5	34.5
,, 4	30	..	3	2	..	35.0
,, 5	30	6	..	..	..	36.0

F.—*Clovers and timothy only.*

No. of mixture.	Timothy.	Broad red clover.	Late flowering red clover.	Alsike.	Wild white clover.	Total. lb.
F. 1	11.25	..	6	..	..	17.25
,, 2	11.25	..	6	..	0.5	17.75
,, 3	11.25	..	..	4	0.5	15.75
,, 4	11.25	..	3	2	..	16.25
,, 5	11.25	6	..	..	..	17.25

I. *Various combinations of grasses only.*

No. of mixture.	Italian rye-grass.	Perennial rye-grass.	Tall oat grass.	Cocksfoot.	Timothy.	Rough-stalked meadow grass.	Total lb.
I. 1	4	10.0	..	10	6	1	31.0
,, 2	2	5.0	..	10	6	1	23.0
,, 3	..	3.5	..	10	6	1	20.5
,, 4	..	..	..	10	6	1	17.0
,, 5	..	..	10	10	6	1	27.0

J.— *Various combinations of grasses with wild white clover only.*—Five mixtures precisely as " I " above with the addition of ½ lb. of wild white clover to each mixture.

K.— *Various combinations of grasses with late flowering red clover only.*—Five mixtures precisely as " I " above (*i.e.*, without wild white clover) with the addition of 3¾ lb. of late flowering red clover to each mixture.

L.— *Various combinations of grasses with alsike only.*—Five mixtures precisely as " I " above (*i.e.*, without wild white clover) with the addition of 2½ lb. of alsike to each mixture.

M.— *Various combinations of grasses with the addition of broad red clover only.*—Five mixtures precisely as " I " above (*i.e.*, without wild white clover) with the addition of 3¾ lb. of broad red clover to each mixture.

N.— *Various combinations of grasses with the addition of both late flowering red clover and alsike.*—Five mixtures precisely as " I " above (*i.e.*, without wild white clover) with the addition of 2 lb. of late flowering red clover and 1¼ lb. of alsike to each mixture.

O.— *Various combinations of grasses with the addition of late flowering red clover, alsike and wild white.*—Five mixtures precisely as " N " above with the addition of ½ lb. of wild white clover to each mixture.

In addition to the above series of mixtures it was the intention to test a full " Clifton Park " mixture and also to grow the grasses in pure plots. The ground did not, however, permit of placing all the replications on the main block of the experiment, with the result that the plots placed elsewhere did not prove comparable, consequently the data from these plots have not been sufficiently reliable to be brought under discussion.

II. Pasture Mixtures. (Mixtures in lb. per acre).

Ga.—*One grass with little wild white clover.*

(1) Perennial rye-grass ..	20 lb.	(2) Crested dogstail ..	20 lb.
Wild white clover ..	1 lb.	Wild white clover ..	1 lb.
(3) Rough-stalked meadow grass	25 lb.	(4) Chewing's fescue ..	20 lb.
Wild white clover ..	1 lb.	Wild white clover ..	1 lb.

Gb.—*One grass with much wild white clover.*—Four mixtures precisely as " Ga " above, wild white clover contributing 4 lb. instead of 1 lb.

H.—*Perennial rye-grass and one other grass with wild white clover.*

(1) Perennial rye-grass ..	5 lb.	(2) Perennial rye-grass ..	5 lb.
Crested dogstail ..	15 lb.	Rough-stalked meadow grass	19 lb.
Wild white clover ..	1 lb.	Wild white clover ..	1 lb.
(3) Perennial rye-grass ..	5 lb.		
Chewing's fescue ..	15 lb.		
Wild white clover ..	1 lb.		

Technique Relative to the Plots.

In the first two harvest years the plots were cut for hay as and when ready, that is to say, those plots with late flowering red clover and timothy predominant in the seeds mixture were cut later than those with broad red clover and the rye-grasses as the chief contributors. In subsequent years all the plots were cut at about the same time—an average date. The plots were cut on a dry day and weighed *in toto* immediately after cutting. At the beginning of the experiment no drying shed facilities were available, so that it was not possible to obtain air-dried weights. All weights for the whole period of the experiment are therefore given as green fodder per rod plot. Samples were taken for botanical analyses. The separations from these samples were weighed air-dry, the percentage contribution consequently being calculated on air-dried produce, and it has been assumed that these calculations apply reasonably accurately to the contributions to the green fodder—any systematic error involved being at all events applicable to all plots alike. In the first harvest year, 328 plots were separately weighed and subjected to botanical analyses; in subsequent years the number of plots brought under critical review was reduced to 82.

Discussion of Results.

The schedule of mixtures will have shown that the various mixtures can be conveniently grouped so that much of the data can be analysed on the basis of averaging a very large number of plots.

The wild white "takes" in the hay mixtures ($\frac{1}{2}$ lb. per acre) were not sufficiently good to influence the results materially, consequently for many purposes the "with" and "without" wild white clover mixtures can be regarded as duplicates and averaged—this applies, for example, to series "I" and "J" and to series "N" and "O."

For convenience the "hay" and "pasture" mixtures will be dealt with separately.

Hay Mixtures.

Before considering in detail the effects of one sown species on another, it will be desirable to review the data bearing upon the aggregate yields for the four harvest years as a whole given by characteristic mixtures, and to consider this evidence in relation to the rapid colonization by unsown species.

Aggregate Yield and Weed Colonization.

The yields for the several series of plots for the four harvest years separately with the contribution of sown species in the hay are given in Table I.

The figures show that the yields for the four years for all the plots together have fallen from 100 in the first harvest year to 65 in the second; to 59 in the third; to but 37 in the fourth; while the contribution of sown species at practically 94 per cent. in the first year had fallen to 77 per cent. by the second; to as low as 35 per cent. by the third, and to the almost negligible contribution of but 10 per cent. by the fourth year. It will be noted that as the contribution of sown species to the hay has fallen, so have the yields from the several types of mixtures levelled up. In the first harvest year the yield from the no-seeding plots was about one-fifth of that of the average of the sown plots; by the

TABLE I.—*Hay mixtures*: *showing for each of the four harvest years the total yield (sown species + weeds) and the percentage contribution of sown species to the total hay crop in the case of the several mixtures grouped into characteristic series. Green fodder in lb. per rod plot.*

Groups.	Type of Mixture.	1st harvest year. 1922.		2nd harvest year. 1923.		3rd harvest year. 1924.		4th harvest year. 1925.	
		Yield	Per cent. sown spp.	Yield.	Per cent. sown spp.	Yield.	Per cent. sown spp.	Yield.	Per cent. sown spp.
A.	Clovers alone	110.9	81	101.1	37	93.5	8	38.5	2
B.	Clovers and perennial rye-grass	133.3	92	104.1	82	83.7	32	61.4	12
Bl.	Clovers and Italian rye-grass	101.6	93	81.2	73	77.5	18	53.7	6
C.	No seeding*	24.1	0	58.7	0	104.0†	0	38.5	0
D.	Clovers and cocksfoot ..	139.1	93	96.3	83	75.0	39	57.2	2
E.	Clovers and tall oat grass ..	158.4	94	100.1	84	81.2	26	54.7	3
F.	Clovers and timothy ..	133.0	96	116.8	73	94.1	18	65.5	2
I. & J.	Various combinations of grasses only‡	131.6	96	64.6	79	71.5	41	37.9	11
K.	Various combinations of grasses with late flowering red clover only	162.9	97	82.7	88	70.3	64	45.3	34
L.	Various combinations of grasses with alsike only	139.1	98	78.3	84	77.5	43	48.0	20
M.	Various combinations of grasses with broad red clover only ..	132.6	96	63.8	83	77.5	46	51.9	9
N. & O.	Various combinations of grasses with late flowering red clover and alsike only‡ ..	140.4	97	73.1	87	71.8	46	42.6	14
	Average yields and average contribution of sown species for each harvest year*	134.8	94	87.4	77	79.4	35	50.6	10
	Relative first harvest year 100*	100	100	65	82	59	37	37	11

* The no-seeding plots are not included in the averages or in the relative figures.

† Plots situated on the lower (deeper and more fertile) soil only available for hay weights, the figure is therefore not comparable to the average figures given for the sown plots.

‡ Average of series with and without wild white clover, the " take " of the wild white clover in these hay mixtures was negligible.

TABLE II.—*To show the contribution of bent (per cent. air dried) to the hay in the second, third and fourth harvest years in the case of plots representing three series of mixtures situated on that portion of the field on which bent re-colonized most rapidly.*

Mixtures.	2nd harvest year. 1923.	3rd harvest year. 1924.	4th harvest year. 1925.
Various combinations of clovers only	70	80	90
Various combinations of clovers with one grass only ..	50	75	59
Various combinations of clovers with three to five species of grasses	12	50	60

second harvest year it was considerably more than half of that of the sown plots, and by the fourth harvest year the non-sown plots were yielding about three-quarters of the crop given by those sown with various mixtures.*

How rapidly and to what extent unsown species, chiefly bent grasses, have dominated the sward is further shown by reference to Table II, in which table the figures represent the state of affairs on plots situated on that part of the field where bent was most aggressive. The figures in both Tables I and II show that clovers alone (not including wild white clover) without grasses are unable to compete with unsown grasses (chiefly bent) and weeds nearly as well as clovers sown with but one grass species, while the addition of three to five grass species tends further to retard weed domination. Various combinations of grasses without clovers are more competent to delay bent and weed domination than are various combinations of clovers without grasses (compare group A and groups I—J in Table I.) Bent and weed domination has been most effectively retarded on those plots where late flowering red clover was included with grasses in the mixtures (see groups K and N—O in Table I).

In the first harvest year the highest yields have been obtained where late flowering red clover was associated with one or more grasses. In subsequent years the comparative yields have been largely upset by differential colonization by unsown species, and are consequently not of much significance in relation to the true yielding ability of the several combinations of species.

Clovers and timothy (particularly late flowering red clover and timothy) would appear, however, to have given the highest yields over the four year period, while the comparative excellence of the yields given by clover and perennial rye-grass is to be noted ; indeed from the gross yield point of view over the four year period, clovers with one grass have yielded just as well as, or better than, clovers with several grasses. The high yield of the timothy—late flowering red clover plots, has been largely due to the fact that these two species reach maturity at about the same time and later than other mixtures

* The yield figure of the non-sown plots for the third harvest year is not reliable, for the reasons explained in the footnote to Table I.

TABLE III.—*To show the percentage frequency (ground analyses) of the chief species in the sward in the fifth harvest year (1926) in the case of plots representing three groups of hay mixtures.*

Mixtures grouped.	Perennial rye-grass.	Italian rye-grass.	Cocksfoot.	Timothy.	Rough-stalked meadow grass.	Crested dogstail.*	Bent*	Yorkshire fog.*	Red clover	Alsike clover.	White clover.*	Yellow suckling clover.*	Miscellaneous weeds.*
Various combinations of grasses only	15.0	Trace.	2.0	0.5	10.0	2.0	29.0	27.0	..	..	9.0	0.5	5.0
Various combinations of grasses with late flowering red clover	24.0	Trace.	3.0	3.0	20.0	1.0	13.0	18.0	1.0	..	5.0	1.5	10.0
Various combinations of grasses with late flowering red clover and alsike clover	25.0	Trace.	2.0	4.0	16.0	2.0	7.0	23.0	0.5	..	4.0	5.0	11.0

* Not included in the mixtures,

as a whole. In the first two harvest years these plots were cut later than other plots—were in fact cut at the correct time for such late plants, and this of course both actually and relatively augmented their yield.

The results of ground analyses made on typical plots in the fifth harvest year (1926) are given in Table III. These figures are interesting as showing that apparently the contribution of sown grasses to the rapidly deteriorating sward has been somewhat increased by the inclusion of late flowering red clover in the mixtures, despite the fact that the clover at this stage was only present in traces on the plots. This fact would probably have been chiefly due to the earlier suppressing effect of the clover on bent grass previously referred to and also further suggested by the figures in the table, but may in part have been due to the influence of the red clover on fertility, and in this connection it is interesting to note that it is the high fertility demanders—perennial rye-grass and rough-stalked meadow grass—that have been chiefly affected. The excessively poor fifth year contribution made by ordinary Danish cocksfoot and American timothy under the conditions of severe competition with bent grasses is a typical and noteworthy result of considerable importance, as is the fact that of the larger grasses perennial rye-grass is the only one to be represented to any economic extent.

A retarding influence of late flowering red clover on the self-establishment of indigenous wild white clover is suggested by the figures in the table. The effect of soil conditions and that of various mixtures on the self-establishment of wild white clover and of rough-stalked meadow grass is a matter demanding careful study. Both are plants which often volunteer in considerable amount at a very early stage on sown swards—rough-stalked meadow grass, however, invariably makes the earliest appearance. The spontaneous colonization of these plants appears to be hastened by sowing mixtures without a nurse crop and by grazing as soon as possible after sowing. Thus in the case of a simple mixture grazed for the first time 10 weeks after sowing (Upper Ridge Field), within 8 months rough-stalked meadow grass, although not sown, was contributing 30 per cent. (tiller counts) to the sward, while wild white clover (also not sown) was present to the extent of 4 per cent.

These figures are of course unusually high, but it is no uncommon thing for both species to have made a spontaneous contribution of 3 per cent. by the first harvest year ; while by the second harvest year, even when hay has been taken in the first year, contributions of 11 per cent. from rough-stalked meadow grass and 7 per cent. from wild white clover have been recorded.

The relation that broad red clover and late flowering red clover respectively may bear to the spontaneous colonization of the two species under review has been studied in connection with red clover nationality trials. The percentage figures hereunder derived from analyses (tiller counts) made on plots sown either with red clover alone or with red clover and one grass species are typical.

	Rough-stalked meadow grass.	*Wild white clover.*	*Experiment number.*
Third harvest year.			
After broad red clover	36.0	3.2	E. 37
,, late flowering red clover ..	27.1	1.1	
,, broad red clover	2.4	10.2	A. 81
,, late flowering red clover ..	6.0	3.2	
Fourth harvest year.			
After broad red clover	32.5	11.7	A. 39 V.
,, late flowering red clover ..	25.7	6.0	

These data appear to bear out the results given by the experiment directly under review, and show that late flowering red clover certainly exerts a greater retarding influence on the spontaneous development of wild white clover than does broad red clover. The figures for the fourth harvest year suggest, however, that the influence is but one of retardation, the delayed colonization being due chiefly to the smothering effect of the late flowering red clover being continued for two harvest years instead of for one, as is the case with broad red clover. The differential effect of the two red clovers on rough-stalked meadow grass is not nearly so well marked—indeed, taking the above results in conjunction with those in Table III, it may be doubted whether late flowering red clover has any greater delaying influence on the entry and spread of this grass than has broad red clover, or whether either clover exercises any appreciable retardation. It is probable in this case that any greater smothering effect of the more vigorous growing late flowering red clover than of broad red is set off by the former species lasting longer on the ground, and thus presumably exercising a greater fertilising effect favourable to the rough-stalked meadow grass.

Yields of Individual Grasses.

The figures in Table I have given gross yields—the sum of sown and unsown species : it is interesting to compare these with the yields given by individual grasses. The results from the series of mixtures B—F have been averaged and are presented in Table IV.

TABLE IV.—*To show the yields given by individual grass species in each of the four harvest years. Data averaged from the series of mixtures B—F. Green weight in lb. per rod plot.*

Species.	1922.	1923.	1924.	1925.	Total wt. sum of 4 years.	Relative with perennial rye-grass 100.
Italian rye-grass	72.0	16.6	11.2	1.8	101.6	53
Perennial rye-grass	112.4	49.6	21.7	7.3	190.0	100
Cocksfoot	123.4	52.5	25.1	0.9	201.9	106
Tall oat grass	163.0	57.6	18.0	1.6	240.2	126
Timothy	73.4	46.1	15.4	0.8	135.7	71
Total of all species per year..	544.2	222.4	91.4	12.4	..	..
Relative with 1st harvest year 100	100	41	17	2	..	..

Comparing these figures with those in Table I, it is interesting to note that the drop in yield in respect of these sown grasses has been far more steep from year to year than in the case of the gross yields, and particularly so in the third and fourth harvest years, when the yield of the sown grasses ceases to be material. The figures confirm those obtained from ground analyses in the fifth year, and show that perennial rye-grass alone of the bulky grasses has carried in appreciable amount into the hay crop of the fourth year ; neither cocksfoot, nor timothy, nor tall oat grass has made a better fourth year contribution than

Italian rye-grass.* It will be observed that tall oat grass and cocksfoot have given the highest yields in the first two harvest years, and largely on account of these high yields these two grasses have also reached the highest aggregate for the four years together. The relatively low yields from timothy may appear contradictory in view of the fact that the timothy—late flowering red clover plots were the highest yielding of the whole experiment ; this is largely due, however, to the fact that timothy has not exercised a depressing influence on the late flowering red clover, which latter heavy yielding plant therefore did itself full justice in the first and second harvest years and contributed very heavily to the hay. The influences of competition will be discussed in detail in a later section. The relative yields of the five grasses are very similar to those given by innumerable pure plot experiments, and serve to emphasize the high yielding ability of cocksfoot in the hay of the first two harvest years and the altogether heavier yields that may be expected from perennial rye-grass than from Italian rye-grass.

Stages in Natural Colonization.

Colonization by bent, Yorkshire fog, and miscellaneous weeds has in the main followed the same major trend on all the plots despite the seeds mixtures sown—ending in final bent domination. The effect of the mixtures has merely been to delay the process : in the case of the plots sown with clovers only, the state of affairs as to weed colonization has always been a year behind that of the unsown plots. Thus by the third harvest year the clover-only plots were carrying about the same amount of bent, namely, roughly 80 per cent., as the no-seeding plots were carrying in the second harvest year : where the mixtures had been more complete and the competition from sown species more vigorous, this degree of bent domination was not attained even by the fourth harvest year. On the no-seeding plots, and to a considerable extent on the clover-only plots the earliest colonization by unsown species was largely due to annual and biennial weeds which, however, rapidly gave place to bent—on the plots representing the more complete mixtures this stage of colonization was very largely bridged, the place of the sown species being taken more directly by bent and Yorkshire fog. During the early stages of bent colonization this grass occurred as large and coarse tufts with species like rough-stalked meadow grass, crested dogstail (to some slight extent), wild white clover, and yellow suckling clover, together with a certain proportion of annual weeds, tending by self-establishment to develop a finer sward between the tufts. By the fourth harvest year most of the no-seeding plots had developed into a close mat of bent, while the clover-only plots still presented the more tufted appearance with a somewhat more varied flora.

Two of the no-seeding plots were fenced off at the commencement of the experiment, and these were not grazed during the five years following sowing. The behaviour of these plots throws further interesting light on natural colonization, the more so as one of the fenced plots was on the heavier, deeper soil, and the other on the lighter, shallower part of the field.

On the lower portion which had not been well cleaned from bent during the previous cropping, this species immediately gained entry, and by the end of the

* Perennial rye-grass by no means invariably does better than cocksfoot in the fourth year : in many of our trials the position has been reversed.

TABLE V.—*To show the percentage occurrence of unsown species in the hay representing the plots as a whole in the second* (1923) *and third* (1924) *harvest years.**

Species.	1923.		1924.	
	Per cent. occurrence.	Order of occurrence.	Per cent. occurrence.	Order of occurrence.
Agrostis spp.	94.6	1	100.0	1
Holcus lanatus	86.9	2	97.6	2
Cerastium vulgatum	76.8	3	78.4	3
Trifolium minus	55.0	4	47.0	5
Chrysanthemum leucanthemum	31.8	5	27.7	6
Rumex spp.	23.2	6	12.1	9
Anthoxanthum odoratum	20.5	7	55.5	4
Carduus spp.	18.6	8	*	*
Crepis virens	10.9	11	15.7	7
Luzula campestris	13.7	9	12.1	9
Bromus secalinus†	10.0	12	4.8	12
Ranunculus spp.	12.3	10	3.6	13
Plantago spp.	7.3	13	7.2	11
Prunella vulgaris	7.3	13	15.7	7
Veronica spp.	7.3	13	*	*
Festuca Myurus†	5.9	16	7.2	11
Lotus corniculatus	5.0	17	1.2	15
Alopecurus geniculatus†	2.7	19	1.2	15
Hypochoeris radicata	3.2	18	1.2	15
Avena flavescens†	1.4	22	..	..
Agropyrum repens	1.8	21	..	..
Achillea Millefolium	2.3	20	2.4	14
Potentilla anserina	0.5	23	..	..
Lathyrus pratensis	0.5	23	..	..
Bromus mollis	0.5	23	..	..
Bellis perennis	0.5	23	..	..
Geranium dissectum	..	..	1.2	15
Taraxacum officinale	..	..	1.2	15

* The figures for 1923 were based on analyses of the hay of representative plots from all sections (220 plots) : those for 1924 were based on analyses of the hay from section "C" only (83 plots). *Carduus* spp. and *Veronica* spp. were confined almost wholly to the upper portions of the field, which did not come into the 1924 analyses.

† These species were introduced as impurities in the seed sown.

Bromus secalinus. In Italian rye-grass, only occurring on the plots upon which this species was sown.

Festuca Myurus. In Chewing's fescue, only occurring on the plots with this species.

Alopecurus geniculatus. In rough-stalked meadow grass, only found on the pasture plots where this grass was sown in large quantity.

Avena flavescens. In tall oat grass, only being found where this species was included in the mixtures.

first harvest year had already taken full charge of the plot—annual and other weeds having little chance to gain entry. By the second harvest year a few plants of white clover, rough-stalked meadow grass, self heal, ox-eye daisy and ragwort were noticeable on the plot. In later years the dominance of bent became almost absolute, the dense mass of un-cut foggage tending to smother all other plants, so that by the fifth year the plot was to all intents and purposes a closed association of bent.

On the lighter soil from which bent had been at least partially cleaned by the previous cultivations, the stages of colonization resembled more closely those occurring on the no-seeding plots subjected to periodic grazing. The sward developed during the first harvest year was of a mixed nature consisting, in addition to annual weeds and yellow suckling clover, chiefly of thistles, bent, rough-stalked meadow grass, white clover, Yorkshire fog, ox-eye daisy and wood-rush. As the years advanced dominance was, however, soon shared between relatively few species, and by the fifth year the dominants were bent, rough-stalked meadow grass, white clover and suckling clover— bent being the most abundant, but not even yet having attained complete mastery.

The sequences in bent colonization as detailed above are of great practical importance, and tend to show how essential it is to graze and if necessary " mow over " fields properly in order to prevent these grasses completely ruining the chances of a developing seeds mixture. The behaviour of the plots under review will be shown, when discussing other experiments, to afford an interesting and instructive contrast to that of plots dealt with in an entirely different manner.

Relative Abundance and Colonizing Power of Unsown Species.

The relative frequency of the species—28 in number—which gained entry on the plots without being advisedly sown is shown in Table V. To these species should be added wild white clover, rough-stalked meadow grass and crested dogs-tail, which have, however, not been included in the table because they were sown on a number of the plots. Four species—*Bromus secalinus*, *Festuca Myurus*, *Alopecurus geniculatus* and *Avena flavescens*—definitely owed their presence to being sown as impurities respectively in Italian rye-grass, Chewing's fescue, rough-stalked meadow grass and tall oat grass. The quite definite relative abundance of these on the plots on which they were inadvisedly sown is worthy of note in view of the fact that in no case did they contribute as much as 1 per cent. to the seed sample in which they were contained.

For the rest, the figures in the table speak for themselves, and tend further to emphasize the completeness of the re-establishment of bent and Yorkshire fog. The high place taken by yellow suckling clover is what would have been expected of this plant, which is strongly indigenous to the soils of West Wales : this species with wild white clover and rough-stalked meadow grass, as the data previously discussed have indicated, representing valuable species with considerable powers of self-establishment and self-colonization.

Detailed Results in the First and Second Harvest Years.

Reference to Table I will show that the sown species held their own comparatively well during the first two harvest years, and consequently it is legitimate to consider the results for these two years in some little detail in respect of yield and relative to competitive influences of one species on another.

Productivity at Periods other than at Hay Harvest.

The yield on the several plots was estimated at various periods on a scale of marks 0—100. The more important of these estimates are shown in Table VI. The influence of Italian rye-grass on the yield during the late autumn of the seeding year is well shown. Thus, comparing all mixtures with Italian rye-grass with all mixtures with perennial rye-grass (without Italian rye-grass)

TABLE VI.—*To show estimated yield from typical groups of mixtures at various periods other than in the hay crops. Maximum yield for each period placed at* 100.

Group symbol.	Mixtures.	Autumn of seeding year. 24/10/21	Early spring 1st harvest year. 11/4/22	Aftermath 1st harvest year. 8/8/22	Early spring 2nd harvest year. 11/4/23
A.	*Clovers only.*				
	Late flowering red clover alone ..	43	22	45	8
	Alsike clover alone	53	12	10	8
	Broad red clover alone	60	25	100	neg.
B.	*Clovers and one grass.*				
	Italian rye-grass and late flowering red clover	100	98	35	64
	Italian rye-grass and alsike ..	94	100	20	53
	Italian rye-grass and broad red clover	94	95	90	53
	Perennial rye-grass and late flowering red clover	80	75	50	78
	Perennial rye-grass and alsike ..	86	72	10	81
	Perennial rye-grass and broad red clover	74	69	100	73
D.	Cocksfoot and late flowering red clover	71	60	45	92
	Cocksfoot and alsike	63	61	35	86
	Cocksfoot and broad red clover ..	67	65	100	89
E.	Tall oat grass and late flowering red clover	60	65	88	83
	Tall oat grass and alsike	57	61	85	78
	Tall oat grass and broad red clover	53	57	91	78
F.	Timothy and late flowering red clover	33	31	33	64
	Timothy and alsike	43	33	18	68
	Timothy and broad red clover ..	36	39	80	65
I. & J.	*Grasses only.*				
	Perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass with Italian rye-grass	82	86	31	70
	Perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass	67	69	28	80
	Cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	60	49	30	70
K.	*One clover and several grasses.*				
	Late flowering red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass with Italian rye-grass	90	91	34	72
	Late flowering red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass	53	69	45	100
	Late flowering red clover, cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	60	61	40	92
M.	Broad red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass with Italian rye-grass	75	82	78	72
	Broad red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass ..	53	65	90	73
	Broad red clover, cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	69	68	100	78

the average autumn productivity of the former is 89, and that of the latter 76. By the late autumn, late flowering red clover had been quite as productive as broad red, the average figure in mixtures for the two clovers being 64 and 61 respectively. The autumn productivity of the timothy mixture has been slight. Italian rye-grass has exercised an even greater influence on productivity during the early spring of the first harvest year than in the autumn of the seeding year. A comparison of the Italian rye-grass mixtures with the perennial rye-grass mixtures gives the following average figures strikingly in favour of the former species, 92 : 69. The poor early spring productivity of the timothy mixtures is particularly to be noted. Higher spring yields might have been expected from mixtures with the early growing tall oat grass, but even at the seed rates employed (30 lb. in simple mixtures and 10 lb. in many-species mixtures) a really dense stand of this grass was not achieved. Broad red clover has influenced aftermath yields in the first harvest year more than any other single species ; the inclusion of this species has in every instance ensured a high aftermath yield.

The very poor aftermathing ability of timothy and of alsike is conclusively shown, the two species together having given the poorest aftermath of all the plots. The tall oat grass mixtures have been amongst the highest producers of aftermath. By the early spring of the second harvest year the Italian rye-grass had thinned considerably, so that mixtures including this species have not given striking early spring yields. The cocksfoot and tall oat grass mixtures have been amongst the highest yielding early in the spring of the second harvest year.

Hay Yields.

The data for hay yields in the first and second harvest years have been set out in Table VII in greater detail than in Table I.

The influence of late flowering red clover on hay yield is particularly striking. Mixtures including late flowering red clover have given an average yield of 146.5 lb. per rod in the first harvest year, while corresponding mixtures with broad red clover have given 131.5 lb. per rod. In the second harvest year the figures are even more strikingly in favour of the mixtures with late flowering red clover, the average figure being :—late flowering red clover mixture 101 and broad red clover mixture 74. The figures as a whole in the table show conclusively that late flowering red clover influences hay yields in the first two harvest years more than does any other species.

In these trials alsike clover has contributed well to the one-grass-one-clover mixtures, having done quite as well as broad red clover in the first harvest year and very decidedly better than the red clover in the second harvest year. This is typical of the behaviour of alsike on certain fields, its reactions being very variable, but when reasonably well established in mixtures it frequently makes a better contribution than broad red clover in the second harvest year—but its poor aftermathing ability previously referred to must always be remembered. The yields from the grass-only mixtures have not compared well with the yields from grass and clover mixtures in either the first or second harvest year. It is interesting to note that the one-grass-one-clover mixtures have yielded nearly as well in the first harvest year as the several-grasses-one-clover mixtures ; while the simpler mixtures have given decidedly the heavier yields in the second harvest year. It thus follows that when hay is required from a two year ley in

TABLE VII.—*To show the hay yields (including sown and unsown species) in lb. per rod (green fodder) for the first and second harvest years in the case of typical mixtures (series C. and D. only).*

Group symbol.	Mixtures.	1st harvest year. 1922.	2nd harvest year. 1923.
A.	*Clovers only*		
	Late flowering red clover alone	138.5	124.5
	Alsike clover alone	82.0	93.3
	Broad red clover alone	91.8	60.0
B.	*Clovers and one grass.*		
	Italian rye-grass and late flowering red clover	109.0	101.3
	Italian rye-grass and alsike	101.0	80.0
	Italian rye-grass and broad red clover	94.3	62.3
	Perennial rye-grass and late flowering red clover	137.5	115.8
	Perennial rye-grass and alsike	134.3	106.5
	Perennial rye-grass and broad red clover	128.5	75.8
D.	Cocksfoot and late flowering red clover	132.6	98.0
	Cocksfoot and alsike	132.5	98.3
	Cocksfoot and broad red clover	151.8	86.8
E.	Tall oat grass and late flowering red clover	166.5	109.3
	Tall oat grass and alsike	151.5	99.3
	Tall oat grass and broad red clover	157.0	75.8
F.	Timothy and late flowering red clover	142.9	129.8
	Timothy and alsike	120.5	105.8
	Timothy and broad red clover	122.0	100.0
I. & J.	*Grasses only.*		
	Perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass with Italian rye-grass	144.0	64.0
	Perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass	120.0	68.0
	Cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	129.0	68.0
K.	*One clover and several grasses.*		
	Late flowering red clover, perennial rye-grass, cocksfoot, timothy, and rough-stalked meadow grass with Italian rye-grass	158.5	75.3
	Late flowering red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass	178.6	85.5
	Late flowering red clover, cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	146.8	94.5
M.	Broad red clover, perennial rye-grass, cocksfoot, timothy, and rough-stalked meadow grass with Italian rye-grass	136.0	63.0
	Broad red clover, perennial rye-grass, cocksfoot, timothy and rough-stalked meadow grass without Italian rye-grass	137.0	65.5
	Broad red clover, cocksfoot, timothy and rough-stalked meadow grass without either rye-grass	125.0	68.0

both the first and second harvest years, as high yields can be secured from simple two species mixtures as from those of a more complicated nature. In this connection the figures add emphasis to the well established fact that perennial rye-grass makes for heavier hay crops than does Italian rye-grass in the first harvest year, but perhaps more interesting is the evidence from the cocksfoot and tall oat grass plots (both grasses which also aftermath well) showing that these grasses sown alone with a clover give as heavy (or heavier) first harvest year hay crops as perennial rye-grass with a clover. It is in the second harvest year in these particular trials that perennial rye-grass has shown to the best relative advantage in simple mixtures—a result which was perhaps hardly to be expected, and which will be further alluded to when discussing competition.

The Influence of One Species upon Another.

The general influence of sown species on unsown species has been previously discussed. It now remains to deal with the effect of one sown species on another. From the economic aspect, competition has to be considered from two chief points of view: firstly, the balance of the mixture, and secondly, the aggregate yield. In the case of a short duration hay ley the balance of the mixture is only affected to any really important extent by the proportion of clover to grass in the hay crop. In longer duration mixtures the balance of the mixture will have been completely upset if the longer duration species are crowded out and killed during the early months of the life of the ley. In so far as aggregate yield is concerned, provided the ratio clover to grass is maintained at a correct level, if one grass crowds out another and in so doing compensates, or more than compensates, for the depressed yield of the less successful grass, no very material harm will have been done to the current hay crop.

If, however, the species that has suffered suppression is inherently more persistent than the aggressor species and a long duration sward is in view, then the future development of the sward will have been adversely affected. In a short duration mixture, to sow non-aggressive species with highly aggressive species from the point of view of increasing the hay yield is of course a pure waste of seed, and is only justified if there is a reasonable hope that the species of negligible significance in the hay crop will contribute in appreciable amount to the aftermath or to non-hay period grazing.

The data obtained during the first and second harvest years provide material for examining competitive influences from the above points of view.

The Effect of one Clover on another in All-clover Mixtures.

Williams (23) has shown that when a late flowering red clover is sown in competition with a broad red, the latter tends to suppress the former in the first harvest year, but that the extra yield from the early clover more or less counterbalances the reduced yield from the late clover, and consequently the aggregate yield from the two together is very similar to that from the late clover alone. The present trial gives further information on this point and affords evidence relative to alsike clover also. The figures in Table VIII are interesting in this connection.

In this case in the first harvest year, plots sown with late flowering red clover and alsike, or with late flowering red clover, alsike, and broad red clover have not given as high yields as those sown with late flowering red clover alone, although compared with the yields from broad red clover and alsike alone it

TABLE VIII.—*To show the effect of one clover on another in all-clover mixtures. Yields in terms of clover only in lb. of green fodder per rod plot.* 1922—1923.

Clovers.	First harvest year.				Second harvest year.	
	Yield of clover.	Per cent. clover.*			Yield of clover.	Per cent. clover.*
		Late flowering red.	Broad red.	Alsike.		
Late flowering red clover alone ..	132.0	93	..	..	58.2	49.5
Alsike clover alone	76.5	88	..	..	30.9	36.0
Broad red clover alone	84.0	90	..	..	2.3	5.0
Late flowering red clover and alsike	117.0	67	..	26	56.6	49.0‡
Late flowering red clover, broad red and alsike	119.0	20†	20†	52	25.0	27.0§

* The balance consisting of unsown weed species.

† Separation between the two varieties of red clover was impossible, late flowering red clover and broad red together contributed 40 per cent. to the total produce.

‡ Chiefly late flowering red clover.

§ Still an appreciable amount of alsike.

will be apparent that, as observed by Williams, reduction in the late flowering clover has been largely compensated for by the yields from the other clovers. The second harvest year data seem to show that during the first harvest year broad red clover exerted a greater early smothering effect on late flowering red than did alsike clover, for the plot with late flowering red and alsike by the second year consisted predominantly of the former clover, and yielded practically as heavily as the pure plot of late flowering red clover.

The addition of broad red clover to alsike and late flowering red clover had so reduced the late red variety by the second year that the yield was even less than that given by the pure alsike plot.

It is thus evident from the data that late flowering red clover, as shown by the earlier trials of Stapledon and Davies (20), is the aggressor species when sown alone with alsike* ; it is equally evident that broad red clover exercises a greater retarding influence on late flowering red clover than it does on alsike. Thus when the three clovers are sown together, alsike may actually become the aggressor species, with results that can only be disastrous by the second harvest year. Evidence from other trials tends to suggest that the suppressing effect of broad red clover on late flowering red clover is due as much (or more) to competition during the autumn of the seeding year as during the period of hay production in the first harvest year.

The Effect of Different Clovers on the Grasses in Simple Two-Species (One-Grass-One-Clover) Mixtures.

The retarding influence of grasses on clovers has been frequently alluded to by writers on seeds mixtures : the influence of clovers on grasses, although

* Always provided the "takes" of the two clovers have been equally good. Cases have come under observation where the alsike has established well and the red clover poorly, when of course the position may be reversed.

TABLE IX.—*To show the influence of clovers on grasses in simple two-species mixtures. The yields (green fodder in lb. per rod) are the contribution made by the grass species only and the percentages are the contribution made by the grass species to total yield (grasses, clovers and weeds).* 1922—1923.

	First harvest year.						Second harvest year.	
Clovers.	Broad red clover.		Late flowering red clover.		Alsike clover.		Late flowering red clover.	
Grasses.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.
Italian rye-grass ..	86.5	82	53.7	48	75.8	74	26.0	33.9
Perennial rye-grass	105.9	67	111.1	71	120.3	74	48.7	50.4
Cocksfoot	141.1	83	114.9	72	123.3	83	50.4	59.2
Tall oat grass ..	189.9	94	152.0	80	170.6	94	58.9	66.6
Timothy	86.9	63	64.3	43	79.7	59	50.6	50.6
Averages	122.1	..	99.2	..	113.9	..	46.9	..

commented upon by Johnstone-Wallace (10) and others has, however, received comparatively little attention. When considering the results of the present trials it must be remembered that the sowing date was too late to do the clovers full justice, and consequently the grasses started with an initial advantage—a happening, however, which not infrequently occurs under ordinary farm practice. Data are presented in Table IX which show the state of affairs as revealed by the evidence immediately under review. Critical experiments designed to elucidate the biological factors influencing competition (Stapledon and Davies (19)) have shown that the date of "putting up" to hay and of cutting the hay crop exercises a profound influence on the inter-specific adjustments. The later the hay is cut the greater is the preponderance of clovers, and by that much the more is the dominating influence of late flowering red clover emphasized. The evidence from the data in the table must be judged in the light of these facts, for the plots with Italian rye-grass and with timothy (both later flowering grasses than the other three grass species) were cut later than the other plots. The chief point which emerges is that late flowering red clover exercises a greater retarding influence on the grasses than does either broad red clover or alsike. The yield data previously discussed will, however, have shown that this highly productive plant in practically all cases more than counterbalances by its own increased yield any suppressing effect it may have had on other species. Cocksfoot and tall oat grass will be seen to be the two species of grasses which have been able to yield most heavily in competition with clovers; they are species which are least likely to be dominated by late flowering red clover. The case of timothy is interesting, and is in complete agreement with data obtained by Williams (24) in connection with his clover trials, late flowering red clover exerting an altogether greater depressing influence on timothy yield than does broad red clover. Late flowering red clover may almost be regarded as the aggressor species when sown with timothy. It will be seen from the present data that the clover contributed more heavily than the grass in the first harvest year, and practically as heavily as the grass

TABLE X.—*To show the influence of grasses on clovers in simple two-species mixtures. The yields (green fodder in lb. per rod) are the contribution made by the clover species only, and the percentages are the contribution made by the clover species to the total yield (grasses, clovers and weeds).* 1922—23.

Grasses.	Italian rye-grass.		Perennial rye-grass.		Cocksfoot.		Tall oat grass.		Timothy.	
Clovers.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.
				First	*harvest*	*year.*				
Broad red clover	16.9	16	39.5	25	13.6	8	8.1	4	45.5	33
Late flowering red clover	43.7	39	36.0	23	36.5	23	32.3	17	75.4	52
Alsike clover	20.5	20	19.5	12	20.8	14	5.5	3	45.9	34
				Second	*harvest*	*year.*				
Broad red clover	5.0	10	2.7	4	1.6	2	1.0	1	3.4	3
Late flowering red clover	32.9	43	30.4	31	19.2	24	21.6	30	27.1	27
Alsike clover	26.9	38	25.0	28	6.4	8	7.4	8	10.2	10

in the second harvest year. This has also been the case in some of the trials conducted by Williams above referred to. It is, of course, the high contribution of the bulky late flowering red clover which is chiefly responsible for the heavy yields always given by timothy and late flowering red clover in the first and second harvest years—the fact is these two late maturing plants are admirably complementary for the production of heavy hay crops, and by virtue of the considerable clover contribution are responsible for a hay of high nutritive value. If perennial rye-grass—late flowering red clover plots are compared with timothy—late flowering red clover plots it will be noted (see Table VII) that the latter plots outyielded the former in both the first and second harvest years; in both years, however, the rye-grass contribution outyielded the timothy contribution, and the increased yield of the "timothy" plots is due solely to the greater dominance and luxuriance of the highly productive late flowering red clover.

The Effect of Different Grasses on the Clovers in Simple Two-Species (One Clover and One Grass) Mixtures.

The data presented in Table X, which are the counterpart of those presented in Table IX, show the effect of the grasses on the clovers in simple two-species mixtures.

Comparing the yield and percentage figures given in the two tables it will be readily seen that the grasses have been the aggressor species, and with the sole exception of timothy (when in conjunction with late flowering red clover) have yielded more heavily than the clovers.

Even in the first harvest year, broad red clover and alsike have suffered far more than late flowering red clover from competition with the grasses. The quick growing tall oat grass when sown in large amount has shown a greater depressing influence on the clovers than has Italian rye-grass, while perennial rye-grass, although exercising less effect on broad red clover than Italian rye-grass, has had a more depressing influence on late flowering red. Cocksfoot has depressed broad red clover to a greater extent than either of the rye-grasses, while its influence on late flowering red has been very similar to that of perennial rye-grass. All three clovers have attained their highest absolute and proportionate yields in combination with timothy. In the second harvest year Italian rye-grass ceases to hamper the clovers to any appreciable extent, and we find both late flowering red clover and alsike attain their highest yields on the with-Italian rye-grass plots. The most interesting comparison is that between the with-cocksfoot and with-perennial rye-grass plots, when we see that cocksfoot in the second harvest year has had a very decidedly greater depressing effect on the clovers than has the rye-grass.

The data serve to show that the influence of grasses on clovers is by no means confined to the effects of the rye-grasses, and that when cocksfoot and tall oat grass are not themselves hampered by being set in competition with the rye-grasses they are able to handicap clovers to at least as great an extent as are the rye-grasses themselves. The very striking influence of cocksfoot in both the first and second harvest years is important, and is in keeping with data from other trials and with results reported by Scandinavian workers. Thus cocksfoot must be regarded as a grass with a definitely depressing influence on clovers, and especially on late flowering red clover in the second harvest year.

TABLE XI.—*To show the effect of one grass on another in many-species mixtures. The figures represent yields of the individual grasses contributing to the various mixtures in the first and second harvest years. Average of series I, J, K, L, M, N and O. Green fodder in lb. per rod.* 1922—23.

Mixtures.	Italian rye-grass.		Perennial rye-grass.		Cocksfoot.		Timothy.		Rough-stalked meadow grass.		Tall oat grass.	
	Harvest year.											
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Italian rye-grass 4 lb.; perennial rye-grass 10 lb., with cocksfoot, timothy and rough-stalked meadow grass	46	3	42	22	36	20	10	4	3	1	..	..
Italian rye-grass 2 lb. and perennial rye-grass 5 lb., with the three other species ..	37	2	40	21	49	22	6	5	6	1	..	..
Perennial rye-grass 3½ lb., with the three other species	..	..	48	21	66	25	11	7	5	1	..	..
Cocksfoot, timothy and rough-stalked meadow grass without rye-grasses	..	..	..	..	94	42	16	13	9	1	..	..
Tall oat grass, 10 lb., with the three other species	..	..	..	..	68	18	12	7	7	1	38	25

The Effect of One Species on Another in Many-Species Mixtures.

The influence of one grass on another is very considerable in complicated mixtures. The magnitude of this inter-specific competitive effect is well shown by the figures in Table XI, which may be considered as of considerable significance having regard to the number of plots that it has been possible to average to provide the data. The Italian rye-grass contribution in the first harvest year has been increased when the seeding has been increased from 2 lb. to 4 lb. per acre. Five pounds of perennial rye-grass in competition with 2 lb. of Italian rye-grass have been responsible for practically as heavy a yield of this grass in both the first and second harvest years as have 10 lb. in competition with 4 lb. of Italian rye-grass. Three and a half pounds of perennial rye-grass when Italian rye-grass has been excluded have, however, given a heavier yield in the first harvest year than the larger seedings in competition with Italian rye-grass. The yield of cocksfoot in the first harvest year (10 lb. per acre in all cases) has been decreased to a marked extent by the inclusion of Italian rye-grass, and in direct proportion to the amount included. Perennial rye-grass and tall oat grass have both depressed cocksfoot yield to a very similar extent. Cocksfoot yields more abundantly in both the first and second harvest years when not set to compete with the rye-grasses or tall oat grass than when sown with them. The same is seen to be true of timothy, and in the first harvest year of rough-stalked meadow grass. It is interesting to note that cocksfoot when sown without either rye-grass in a many-species mixture yields more heavily in both the first and second harvest years than does perennial rye-grass when included in such mixtures, while cocksfoot when competing with little rye-grass also exceeds the latter species in yield. None the less the with-perennial rye-grass mixtures tend to give higher gross yields in both the first and second harvest years than do the without-perennial rye-grass mixtures; this is undoubtedly due to the greater smothering effect of cocksfoot than of perennial rye-grass on the clovers and particularly on high yielding late flowering red clover previously referred to.

The smothering effect alike of the two rye-grasses, tall oat grass, and cocksfoot on timothy is well shown by the figures in the table, and is further emphasized by the fact that when timothy was sown alone with broad red clover this grass yielded 87 lb., or over five times as much as when also put to compete with the vigorous growing grass species. Aggressive Italian rye-grass on the other hand hardly yielded twice as large a bulk when sown alone with broad red clover as when included in a many-species mixture.

The general relationship of the various species to each other is further shown by the summary figures presented in Table XII.

In so far as the effect of one grass species on another is concerned the figures prove conclusively that tall oat grass and the two rye-grasses are the aggressor species, and in proportion as the rye-grass seeding is increased so will the yield of cocksfoot, timothy, and rough-stalked meadow grass be decreased. A very interesting point emerges relative to clover suppression, namely, that the rye-grasses added in considerable amount to a mixture already including cocksfoot and the other grasses in considerable quantity have an altogether greater effect than the results from one-grass-one-clover mixtures would have led one to expect. This effect is the more surprising having regard to the suppressing influence of cocksfoot alone on clovers as previously demonstrated. It would appear as if the mixed canopy derived from a number of tall growing grass species exerts a more completely shading effect on the clovers early in the season than does

TABLE XII.—*To show the influence of the two rye-grasses and of tall oat grass on the other ingredients in many-species mixtures during the first and second harvest years. Yields of* (1) *the sum of cocksfoot, timothy and rough-stalked meadow grass*; (2) *the sum of sown clovers*; *and* (3) *the sum of weeds, as green fodder in lb. per rod.* 1922—1923.

Mixtures.	Sum of cocksfoot, timothy and rough-stalked meadow grass. (1)			Sum of sown clovers. (2)			Sum of weeds. (3)		
	Harvest years.								
	1st	2nd	1+2	1st	2nd	1+2	1st	2nd	1+2
Cocksfoot, timothy and rough-stalked meadow grass with clovers without either rye-grass or tall oat grass ..	119	50	169	53	7	60	6	13	19
Cocksfoot, timothy and rough-stalked meadow grass with clovers and tall oat grass, but without either rye-grass	88	25	113	50	5	55	5	9	14
Cocksfoot, timothy and rough-stalked meadow grass with clovers and with 3½ lb. of perennial rye-grass only ..	82	29	111	50	6	56	4	10	14
Cocksfoot, timothy and rough-stalked meadow grass with clovers and with 7 lb. of the two rye-grasses ..	60	26	86	15	5	20	5	10	15
Cocksfoot, timothy and rough-stalked meadow grass with clovers and with 14 lb. of the two rye-grasses ..	49	21	70	14	7	21	3	11	14

the canopy developed by any one single grass species. This is a matter demanding more detailed study, for it has an intimate bearing on the whole question of complex *versus* simple mixtures.

The relation of the various suppressing effects under consideration has not had such a profound influence on the gross yields from the several plots as might perhaps have been expected. The statement hereunder (compiled from Table VII) exemplifies the state of affairs:

	Gross yield of plots in lb. green weight per rod plot.		
	1st harvest year.	*2nd harvest year.*	*Sum of 1st and 2nd harvest years.*
Cocksfoot, timothy and rough-stalked meadow grass+clovers and without rye-grasses ..	133	77	210
Cocksfoot, timothy and rough-stalked meadow grass+clovers and with perennial rye-grass only	145	73	218
Cocksfoot, timothy and rough-stalked meadow grass+clovers and with both rye-grasses ..	146	67	213

In the first harvest year the addition of rye-grasses has somewhat increased the yields, while in the second harvest year the results have been in the opposite direction, with the final result that for the sum of the hay yields of the two harvest years the three groups of mixtures have shown no very material difference in gross yields. It follows, therefore, that as far as hay yields are concerned, in the first two harvest years the competitive influence of one species on another is very largely, if not wholly, counterbalanced by the increased productivity of the aggressor species. The general lesson from the evidence here discussed appears to be quite obvious—namely, that there is no point in using a complicated mixture for a two year ley, and that two heavy hay crops can be assured provided late flowering red clover is employed, and provided also heavy seedings of both the rye-grasses together with cocksfoot and other tall growing grasses are not put to compete with the clover.

Summary as to the Effect of One Species on Another.

A critical study of the factors influencing competition is deferred to the second article in this bulletin. It may, however, serve a useful purpose to summarize the evidence given by the trial under review in the form of a simple statement as to the observed effect of one species on another.

During the first harvest year broad red clover exercises a definitely suppressing effect on late flowering red clover : this influence is not so well marked on alsike clover. Late flowering red clover exercises a suppressing effect on alsike clover. The red clovers and alsike tend to retard the development of white clover, late flowering red clover having the most pronounced influence.

Although in the main it is the grasses which tend to hamper the development of the clovers, none the less late flowering red clover in particular may exercise a definitely depressing influence on the grasses. Late flowering red clover may retard the development of timothy to a considerable extent. Cocksfoot yields more highly than other grasses in competition with the late clover.

The influence of grasses on clover development is at its greatest when several different species of grasses are included in the mixture. The addition of the rye-grasses, expecially Italian rye-grass, to a mixture including cocksfoot and timothy, for example, adds enormously to the suppressing effect of the grasses as a whole on the clovers as a whole.

Broad red clover and alsike clover are handicapped more seriously by undue competition with grass species than is late flowering red clover.

In simple mixtures with only one grass species, cocksfoot has shown itself able to depress clover development to as great an extent as, or to an even greater extent than, has either Italian rye-grass or perennial rye-grass. Timothy interferes with the development of the clovers less than do any of the other larger grasses.

The rye-grasses (particularly Italian rye-grass) have a depressing effect on cocksfoot, timothy, and rough-stalked meadow grass; tall oat grass also tends to retard the development of these grasses.

Cocksfoot growing with timothy is the aggressor species.

Pasture Mixtures.

Reference to the schedule of mixtures (p. 10) will show that the pasture mixtures consisted (*a*) of wild white clover sown either with perennial rye-grass alone, crested dogstail alone, rough-stalked meadow grass alone, or Chewing's fescue alone; and (*b*) of wild white clover and perennial rye-grass sown with either crested dogstail or rough-stalked meadow grass or Chewing's fescue. The "pasture" mixtures were therefore of the simplest kind, and, as has been explained previously, were treated as hay plots and were never managed properly with a view to creating long-lasting pasture swards, for like the rest of the plots they were from the outset subjected to severe competition with bent grasses.

TABLE XIII.—*To compare* (1) *the hay yields of "hay" mixtures with those of "pasture" mixtures; and* (2) *the yields from perennial rye-grass, crested dogstail, and Chewing's fescue respectively in the "pasture" mixtures with the yields of perennial rye-grass and cocksfoot respectively in the "hay" mixtures. The weights given are the aggregate yields from sown species only; in lb. green weight per rod plot based on hay yields in all cases.*

	Mixtures or species.	Harvest years.				Sum of 4 harvest years.
		1922.	1923.	1924.	1925.	
I.	Hay mixtures	165	59	37	7	268
	Pasture mixtures	85	39	32	9	165
II.	Perennial rye-grass in hay mixtures ..	112	49	22	7	190
	Cocksfoot in hay mixtures	123	52	25	1	201
	Perennial rye-grass in pasture mixtures	103	40	32	8	183
	Crested dogstail in pasture mixtures..	63	20	24	9	116
	Chewing's fescue in pasture mixtures..	7	30	36	4	77

Yields.

The chief yield data on the basis of sown species only are given in Table XIII. As was to have been expected, the aggregate yields during the first two harvest years and for the sum of the four harvest years were much greater for the "hay" mixtures (including the larger grasses and the larger clovers) than for the "pasture" mixtures (including only white clover, and perennial rye-grass alone of the larger grasses). It is of considerable significance to note, however, that the sown species in the "pasture" mixtures were yielding practically

as heavily as the sown species in the " hay " mixtures by the third harvest year ; while by the fourth harvest year the yields given by the sown species were actually in favour of the " pasture " mixtures.

The figures in Part II of the table comparing the yields of the individual " pasture " grasses with the yields of the individual " hay " grasses are very interesting with reference to the behaviour of crested dogstail and Chewing's fescue. By the third harvest year, crested dogstail has given practically the same yield as cocksfoot, and taking the average of the " hay " and " pasture " figures for perennial rye-grass, it will be seen that crested dogstail has not been much out-yielded by the rye-grass.

By the fourth harvest year crested dogstail has yielded as highly as, or more highly than, any other species included in the whole experiment. This result is in keeping with evidence obtained from experience gained over a large number of years in the district, and speaks eloquently for the value of dogstail as a permanent species under conditions unfavourable to more productive grasses. The low yield of Chewing's fescue in the first harvest year was due to poor initial establishment, while the relatively good yield by the second year was rendered possible by the fact that germination and establishment have taken place to a marked extent subsequent to the seeding year.* In the third harvest year, Chewing's fescue was the most heavy yielding species in the whole experiment—the plots at that time were very striking and in comparison with the more complicated mixtures surprisingly productive. It will be noted that Chewing's fescue alone gave probably as heavy a yield as the sum of all the sown species in the average of the " hay " mixtures. By the fourth year, this fescue had been largely dominated by the bent grasses, and its contribution, though superior to that of cocksfoot, was considerably less than that of perennial rye-grass or crested dogstail. This result shows that by heavy seeding productive establishment of Chewing's fescue can be achieved, and suggests that under proper management this species could be retained on swards in good amount for considerable periods. In view of the fact that it is a grass which winter-burns both early and badly, and is at all times unpalatable to stock, the evidence as a whole so far collected at the Station suggests that it is a species that should be included in seeds mixtures only in quite exceptional cases, and on very poor land.† The leaves of crested dogstail on the other hand are at all times palatable, and it is one of our most winter-green grasses. Rough-stalked meadow grass did not yield heavily but gave rise to an excellent sward, and on the plots with perennial rye-grass and wild white clover, and until dominated by the bent grasses, gave perhaps the most winter-green of all the swards resulting from any of the mixtures.

White Clover.

The results with white clover were very interesting and very suggestive up to the end of the second harvest year, and to some extent into the third harvest year ; subsequently the intervention of the bent grasses so hampered the development of the clover that initial advantages were obscured.

* The phenomenon of delayed germination has been alluded to in a previous bulletin (21), and will be further discussed in the next article.

† In New Zealand this species is proper to areas of very poor fertility, and is classed by Bruce Levy (12) as one of the lowest fertility demanders.

TABLE XIV.—*To show the yields in lb. green fodder per rod plot from plots sown with perennial rye-grass and wild white clover and with white Dutch clover respectively in the first and second harvest years, and (in brackets) to show the percentage contribution of rye-grasses and clover respectively to the hay.*

	1922.	1923.
Perennial rye-grass and wild white clover	98 (98—1)*	77 (58—20)
Perennial rye-grass and white Dutch clover..	118 (83—8)	73 (56—9)

* The figures to the left within the brackets represent rye-grass, and to the right white clover ; the difference between the sum of the clover and the rye-grasses and 100 constitutes unsown species.

Wild white clover *versus* white Dutch clover.

In one series of mixtures 20 lb. of perennial rye-grass were sown with 1 lb. of white Dutch clover, and in another with 4 lb. of the clover : while in a corresponding series similar amounts of wild white clover were used. In Table XIV the data for the first and second harvest years are given on the basis of the average of the white Dutch plots compared with the average of the wild white plots. It will be seen in the first harvest year that white Dutch with perennial rye-grass gave a decidedly heavier yield than wild white with this grass, but by the second harvest year the wild white plots gave slightly the heavier yield, while the wild white contributed very much more to the hay than did the white Dutch clover.

HEAVY SEEDINGS OF WILD WHITE *versus* LIGHT SEEDINGS AND THE EFFECT OF DIFFERENT " PASTURE " GRASSES ON THE DEVELOPMENT OF WILD WHITE CLOVER.

The results of analyses made of the amount of ground covered by the leaves of wild white clover on various plots in the first, and again in the third harvest years are given in Table XV.

The immediate establishment of wild white clover will be seen to bear a very direct relationship to the amount of seed sown. Thus under each grass species 4 lb. of clover have given a much denser stand than has 1 lb. It is interesting to note that perennial rye-grass, both when the clover is sown in large and small amounts, has handicapped the initial development of the clover more than has crested dogstail or rough-stalked meadow grass.

Careful examination of the plots showed, however, that where rough-stalked meadow grass developed a very dense growth, even this grass could interfere appreciably with the spread of white clover.

By the third harvest year, when the bent grasses were contributing over 50 per cent. to the flora, the sown grass species as such had ceased to have any appreciable influence on the clover, and it will be noted that the white clover contribution on all the plots had levelled up very appreciably.

TABLE XV.—*To show the percentage amount of ground covered by the leaves of wild white clover, when much and when little wild white clover respectively was sown in conjunction with one species of grass.*

Harvest year.	Various grasses with 1 lb. of wild white clover.				Various grasses with 4 lb. of wild white clover.			
	Perennial rye-grass.	Crested dogstail.	Rough-stalked meadow grass.	Chewing's fescue.	Perennial rye-grass.	Crested dogstail.	Rough-stalked meadow grass.	Chewing's fescue.
1922. 1st harvest year ..	3.7	20.2	25.4	18.1	10.7	34.4	43.8	26.2
1924. 3rd harvest year ..	18.3	12.6	7.2	11.4	17.0	10.8	15.4	13.5

It was only on the perennial rye-grass plots where the initial establishment of white clover had been poor that the clover contribution had increased from the first to the third harvest year.

The results in general from these simple pasture mixtures are of great importance, for perfect grazing swards having the characteristics of permanent grass were developed by the first harvest year and were well maintained into the second harvest year. It was only when bent gained the mastery—the result of the type of management necessarily imposed on the plots—that the swards completely deteriorated. The point of practical significance is the fact that by employing large seedings of the wild white clover and appropriate bottom grasses not set in competition with the larger grasses and larger clovers, a dense sward of a " permanent " character can be formed as rapidly as can an open " hay " sward of the ordinary temporary type. These results have an added interest because the evidence they gave led to the setting up of extensive trials with simple pasture mixtures supported by heavy seedings of wild white clover and the bottom grasses. The results of these more extensive trials, when the plots were subjected to various types of management, will be discussed in a later section of the bulletin. The present trial, however, proved three things of equal importance :—(1) The initial establishment of wild white clover can be enormously increased by increasing the seed rate beyond 1 lb. (2) The bottom grasses, if sown in large amount and not set to compete with the larger grasses, can establish themselves quickly and well. (3) No matter how well these bottom grasses and white clover may be established, if the bent grasses are allowed to exercise their smothering influence, complete sward spoliation will take place in an incredibly short time.

E. 40 : SEEDS MIXTURE EXPERIMENT WITH SIMPLE HAY MIXTURES : BARN FIELD : SOWN 1923.

This experiment was designed to test the behaviour of indigenous strains of perennial rye-grass, cocksfoot, and tall fescue compared with the ordinary commercial strains in simple hay mixtures, and also to provide further evidence relative to competition between one species and another.

The Field : Previous Cropping.

The field had been in grass from about 1909 till 1922, when it was ploughed and sown in winter oat trials. The soil was a clay-loam of fairly high fertility.

The mixtures went down under decidedly better conditions than those on Penglais Field (E. 19, previously considered)—but the field was by no means clean ; in this case it was *Ranunculus repens* and *Bellis perennis* which gained most rapid re-entry—Yorkshire fog and the bent grasses not entering into competition with the sown species to anything like the same extent as on Penglais.

Sowing and Subsequent Treatment.

The seeds mixtures were sown on May 29th 1923, without a nurse crop. Hay was taken from all the plots in each of the four harvest years during which the experiment was continued, and aftermath crops were cut and weighed in the first and second harvest years.

The plots were lightly grazed in the seeding year and during the autumn and winter of each subsequent harvest year. The management on this field, although more satisfactory than on Penglais, was not, however, really well suited to the development of the young seeds—the grazing and consolidation, although more complete than on Penglais, were at no time really heavy enough, nor had the preliminary croppings been of a sufficiently cleaning nature, but since the bent grasses were not nearly as aggressive as on Penglais the developing ley was subjected to decidedly less sustained competition with unsown species. As on Penglais the plots were " put up " to hay before February and cut at a normal date.

The Arrangement of the Experiment.

The plots were 1/100th acre and were sown in triplicate for each mixture.

The Seeds Mixtures.

Six different seeds mixtures were brought under test. These are given in Table XVI in lb. per acre.

TABLE XVI.—*The seeds mixtures in lb. per acre.*

Species and strain.	I.	II.	III.	IV.	V.	VI.
Perennial rye-grass commercial ..	14	..	4	4	..	..
Perennial rye-grass indigenous ..	..	14	..	..	..	..
Cocksfoot commercial	6	6	14	..	6	6
Cocksfoot indigenous	..	..	..	14	..	..
Tall fescue commercial	..	..	..	..	14	..
Tall fescue indigenous	..	..	..	..	..	14
Timothy commercial	2	2	2	2	2	2
Broad red clover (Vale of Clwyd) ..	4	4	4	4	4	4

Mixtures I and II compare commercial with indigenous rye-grass in mixtures, otherwise they are similar ; mixtures III and IV compare commercial and indigenous cocksfoot ; mixtures V and VI compare commercial and indigenous tall fescue.

The indigenous strains did not represent pedigree selections, an outcome of the breeding work now in progress at the Station, but merely some of the earliest aggregate collections of indigenous seed upon which the subsequent critical breeding work has been based. Speaking broadly, these indigenous lots were, however, much more leafy and of later maturity than the ordinary commercial seed with which they were compared.

Technique Relative to the Plots.

All the plots were cut for hay on the same day in each harvest year, and the produce weighed *in toto* green. Samples were taken and dried, and the yields are therefore expressed as air-dried hay. Additional samples were also taken for botanical analyses, while counts were made from time to time on the ground by the methods normally adopted at the Station.

DISCUSSION OF RESULTS.

The "takes" were reasonably satisfactory, except that tall fescue showed considerable evidence of delayed germination and delayed growth, and was therefore not well or fully established until the second harvest year. The "take" of the red clover was also not particularly good, and its contribution to the hay crop was decidedly below normal.

AGGREGATE YIELDS: THE HARVEST YEARS COMPARED.

The commercial mixtures with cocksfoot, perennial rye-grass, timothy and broad red clover can be compared with mixtures of a very similar nature on Penglais (E. 19), for the earlier harvest years, and with comparatively smaller mixtures from Wood Field (E. 34—an experiment discussed in greater detail elsewhere).

The yields from sown species with first harvest year placed at 100 are compared in Table XVII for the four harvest years; the percentage contribution of unsown species (chiefly bent and (or) Yorkshire fog on Penglais and Wood Fields, and chiefly *Bellis perennis* and *Ranunculus repens* on Barn Field) is also shown.

TABLE XVII.—*To compare* (1) *the hay yields of sown species for the four harvest years in the case of E.* 19 (*Penglais Field*) *representing very severe competition with bent grasses; E.* 40 (*Barn Field*) *representing less severe competition with bent grasses; and E.* 34 (*Wood Field*) *representing very severe competition with Yorkshire fog: and* (2) *the percentage contribution of unsown species in each case. The yields in the first harvest year expressed as* 100 *and the others proportionately.*

Experiment.	1st harvest year.		2nd harvest year.		3rd harvest year.		4th harvest year.	
	Yield.	Per cent. weeds.	Yield.	Per cent. weeds.	Yield.	Per cent. weeds.	Yield.	Per cent. weeds.
E. 19: Penglais Field, sown 1921 ..	100	4	38	33	25	54	4	90
E. 40: Barn Field, sown 1923	100	12	41	33	30	44	22	53
E. 34: Wood Field, sown 1923	100	19	33	50	42	54	25	61

In the case of E. 19 and E. 40 the yields of sown species have fallen progressively from the first to the fourth harvest years; but whereas on Penglais bent domination had been almost complete by the fourth year and the yield from sown species had become almost negligible, on the Barn Field the sown species were still contributing nearly half the weight to the hay crop, and still gave over one-fifth of the yield which they gave in the first harvest year. When all the mixtures (commercial and indigenous) on Barn Field (see Table XVIII) are considered, it will also be noted that the sown species on that field maintained themselves far better into the fourth harvest year than on Penglais—

but even so the falling off by the fourth harvest year is very considerable, the average yield being only one-quarter of that in the first harvest year. On Wood Field, the drop in yield of sown species had again been progressive, with the exception of a slight rise from the second to the third year. The Yorkshire fog domination had been considerable from the outset, but by the fourth harvest year it was not as complete as the bent and fog domination on Penglais, and the relative yield of sown species was on a par with that on Barn Field where unsown species had also far from completely re-gained the sward.

TABLE XVIII.—*To show* (1) *the yield in lb. dry fodder per* 1/100*th acre plot of the sown species for each of the four harvest years for the six mixtures*: (2) *the average yields per harvest year of all the plots*: (3) *the relative yields of all the plots from the first to the fourth harvest year*: *and* (4) *the total yield for each mixture for the sum of the four harvest years.*

Harvest year.	Mixtures.						Average.	Relative.
	I. with commercial perennial rye-grass.	II. with indigenous perennial rye-grass.	III. with commercial cocksfoot.	IV. with indigenous cocksfoot.	V. with commercial tall fescue.	VI. with indigenous tall fescue.		
1924	41.7	45.9	46.9	49.9	41.1	39.3	45.8	100
1925	17.4	19.7	20.1	22.3	19.6	18.6	19.6	43
1926	12.9	14.2	12.9	10.9	15.1	15.9	13.3	29
1927	8.8	11.1	10.7	12.1	13.5	11.8	11.3	25
Total for 4 years	80.8	90.9	90.6	95.2	89.3	84.9	..	..

The Various Mixtures Compared.

Data as to yields of sown species for each of the mixtures are given in Table XVIII, from which it will be noted that plots in which indigenous rye-grass predominated (II) have outyielded those in which commercial rye-grass predominated (I), and that the same is true of indigenous cocksfoot (IV) compared with commercial cocksfoot (III). The plots with commercial tall fescue (V) have, however, slightly outyielded those with indigenous (VI). The increased yields from plots with indigenous cocksfoot and indigenous perennial rye-grass are the more interesting when it is remembered that the lots under test represented only preliminary collections and when, as will be shown in connection with other trials, this increased yield is due almost wholly to increased leaf production.

The Yields of the Various Species and Strains Compared.

The yields given by the various species and strains and also their percentage contribution to the total hay crop are shown in Table XIX.

Perennial Rye-Grass.

The indigenous strain of perennial rye-grass outyielded the commercial in each harvest year, and also contributed in higher degree to the total hay crop.

TABLE XIX.—*To show* (1) *the yield in lb. dry fodder per* 1/100*th acre plot of the various species and strains in the various mixtures in each of the four harvest years ; and* (2) *the percentage contribution of each species and strain to the total hay yield.*

Species and strain.	1924.		1925.		1926.		1927.		Total yield for the 4 harvest years.
	Yield	Per cent. contribution	Yield	Per cent. contribution	Yield	Per cent. contribution	Yield	Per cent. contribution	
Perennial rye-grass, commercial	33.2	63.9	14.5	51.4	5.2	22.9	3.6	17.0	57.5
Perennial rye-grass, indigenous	38.3	74.4	16.9	59.9	9.0	34.7	6.6	33.8	70.8
Cocksfoot, commercial ..	6.4	11.5	2.1	6.9	2.3	10.0	1.7	7.7	12.6
Cocksfoot, indigenous ..	6.8	11.6	3.8	13.2	5.6	27.0	7.3	30.4	23.3
Tall fescue, commercial ..	12.6	21.7	11.9	38.6	9.8	40.5	10.0	38.6	44.3
Tall fescue, indigenous ..	11.6	22.6	12.7	42.6	13.4	59.4	8.6	41.3	44.7
Timothy, commercial ..	6.7	12.5	1.5	5.3	0.5	8.1	2.5	12.0	11.6
Broad red clover	2.9	5.3	1.2	4.2	0.5	3.8	1.2	0.4	5.9

The result was most marked in the fourth harvest year when the indigenous gave nearly double the yield of the commercial and contributed nearly twice as abundantly to the total hay yield. It is interesting to note that, as on Penglais Field (E. 19), commercial perennial rye-grass has given an altogether higher yield over the four year period and in the third and fourth harvest years than has commercial cocksfoot.

Cocksfoot.

The indigenous cocksfoot, like the indigenous rye-grass, outyielded the commercial strain in each harvest year, and also contributed more abundantly to the hay yield. The figures for the fourth harvest year are particularly interesting. The commercial strain, as on Penglais Field, by the fourth year had dropped to a position of no significance, while the indigenous strain gave a higher yield than even the indigenous perennial rye-grass, and contributed nearly one-third to the total hay crop. This lasting behaviour of indigenous cocksfoot has been borne out by other trials and is evidently a property of very considerable economic significance. It will be noted that indigenous cocksfoot over the period of the four harvest years has given nearly double the yield of the commercial cocksfoot.

Tall Fescue.

In yield, indigenous tall fescue has not surpassed commercial, although in the third and fourth harvest years it has contributed in greater amount to the total hay crop. In other trials to be referred to, the indigenous tall fescue has outyielded the commercial.

TABLE XIX A.—*To show the yield of aftermath as green fodder in lb. per 1/100th acre plot. The yields include sown and unsown species.*

Harvest year.	I. with commercial perennial rye-grass.	II. with indigenous perennial rye-grass.	III. with commercial cocksfoot	IV. with indigenous cocksfoot	V. with commercial tall fescue	VI. with indigenous tall fescue
1924	12.7	16.7	37.9	44.3	65.9	51.9
1925	14.6	14.2	14.0	16.0	25.9	25.5
Total for the two harvest years	27.3	30.9	51.9	60.3	91.8	77.4
Average of plots for each species	29.1		56.1		84.6	

Aftermath in First and Second Harvest Years.

The yields of aftermath in the first and second harvest years are shown in Table XIX A.

The figures show the poor aftermathing ability of perennial rye-grass compared to both cocksfoot and tall fescue, and bring out strikingly that it is the mixtures with the latter species predominating that contribute the most abundant aftermaths. The indigenous perennial rye-grass has yielded decidedly better aftermath than the commercial, while the figures in favour of the indigenous cocksfoot mixtures are even more convincing. As with the hay yields, the commercial tall fescue has been more effective than the indigenous.

The aftermath produce was botanically analysed in the first harvest year. In mixture I (commercial perennial rye-grass predominant) the rye-grass contributed 28.7 per cent. to the total aftermath crop, while in mixture II (indigenous perennial rye-grass predominant) the rye-grass contribution was 33.1 per cent. In the two cocksfoot mixtures the contributions were—commercial cocksfoot (mixture III) 23.4 per cent., and indigenous cocksfoot (mixture IV) 32.3 per cent. The weed contribution was at its lowest on the plots with indigenous cocksfoot the chief contributing species, namely, 9.5 per cent., compared to 13.8 per cent. on the plots with commercial perennial rye-grass the chief species.

The Influence of One Species on Another.

Data for comparing the influence of one species on another are presented in Table XX.

Tall fescue made very poor establishment and growth by the first harvest year and consequently interfered very little with the development of cocksfoot, timothy, and red clover. It will be noted that 14 lb. of perennial rye-grass hampered the development of these three species in each harvest year much more than did 4 lb. This evidence is in accord with that from Penglais Field (E. 19), while the effect of perennial rye-grass added to other grasses on broad red clover is equally confirmatory, for it will be noted that the broad red clover contribution, although always poor, was greater under 4 lb. of perennial rye-grass than under

TABLE XX.—*To show* (1) *the influence of* 14 *lb. and* 4 *lb. respectively of perennial rye-grass and of* 14 *lb. of tall fescue on the sum contribution of cocksfoot, timothy and broad red clover in each of the four harvest years, and for the aggregate of the four harvest years ; and* (2) *the influence of the above sowings respectively on cocksfoot, timothy and broad red clover in the first harvest year. Dry fodder in lb. per* 1/100*th acre plot.*

	Perennial rye-grass 14 lb.	Perennial rye-grass 4 lb.	Tall fescue 14 lb.
I			
1st harvest year 1924	5.5	18.1	27.5
2nd harvest year 1925	3.4	4.6	6.9
3rd harvest year 1926	5.9	7.2	4.4
4th harvest year 1927	4.8	5.9	3.1
Sum of 4 harvest years	19.6	35.8	41.9
II			
Cocksfoot	4.1*	18.8†	19.6*
Timothy	11.6	12.2	15.1
Broad red clover	3.9	4.8	7.2

* Cocksfoot at 6 lb. per acre.
† Cocksfoot at 14 lb. per acre.

14 lb. It is interesting to note that by the third and fourth harvest years, when tall fescue was in considerable evidence, it had a slightly greater depressing influence on other species than had perennial rye-grass.

The figures in Part II of the table show (as on Penglais Field) that in the first harvest year cocksfoot is very sensitive to competition ; thus 6 lb. per acre with tall fescue (poor contribution in first year) have given a higher yield than 14 lb. per acre set to compete with but 4 lb. of perennial rye-grass, while 14 lb. of perennial rye-grass have reduced the cocksfoot contribution in the first harvest year to comparative insignificance. Timothy in this trial has been relatively less sensitive to competition in the first harvest year than on Penglais Field (E. 19), but reference to Table XIX will show that under competition its yields have been far from satisfactory in the second, third and fourth harvest years ; indeed, it has done even less well than on Penglais Field in these latter years. It seems very doubtful, therefore, if much is to be gained by including timothy (unless possibly in very large amount) with cocksfoot and rye-grass in a general hay mixture.

PERSISTENCY.

The persistency of the species from year to year was estimated by making accurate counts of the number of plants per unit of area. Data collected on these lines at the Station over a number of years have revealed interesting results, and show unmistakeable evidence of delayed germination and delayed growth on the one hand, and of the dying off of the plants on the other. There is often a decided tendency for the number of plants to increase from the first harvest year to the second, which can only be due to delayed germination, or to volunteer appearance of indigenous strains of the sown species. This latter happening is exceptional on the soils on which the various experiments have been conducted,

except in the case of species like white clover, rough-stalked meadow grass and crested dogstail. A rapid fall usually occurs from the second harvest year to subsequent harvest years unless delayed germination is unusually pronounced. Samples of seed of poor quality and of grain weight below the average of the species appear to show delayed germination to a greater extent than do samples representing heavy seed of high quality. It has generally been found, therefore, that the indigenous strains grown at Aberystwyth (under unfavourable climatic conditions) exhibit delayed germination to a greater extent than do the commercial strains. This important matter of delayed germination will be dealt with in greater detail in the second article of this bulletin, but the figures in Table XXI may be regarded as fairly typical of the combined influences of delayed germination on the one hand, and persistency (or the lack of it) on the other, and are here presented merely in order to call attention to the significance of the question in relation to seeds mixtures.*

TABLE XXI.—*To show the relative persistency (number of plants per unit of area) for each species and strain in the second and fourth harvest years compared to the first harvest year (placed at* 100 *for each species and strain). No analyses were made in the third harvest year.*

Harvest year.			Perennial rye-grass.		Cocksfoot.		Tall fescue.		Timothy commercial.	Red clover, Vale of Clwyd.
			Commercial.	Indigenous.	Commercial.	Indigenous.	Commercial.	Indigenous.		
1st.	1924	..	100	100	100	100	100	100	100	100
2nd.	1925	..	94	108	106	141	133	113	34	35
4th.	1927	..	18	41	66	145	69	87	55*	20

* Probably this figure is too high, due to some of the plants separating by vegetative means into separate units.

The figures show that the better yielding ability in the fourth harvest year of indigenous perennial rye-grass and of indigenous cocksfoot than of their commercial counterparts can be very largely explained by the better relative persistency of the indigenous strains. The indigenous cocksfoot has given an increase in number of plants per unit of area successively from the first to the fourth harvest year. In all other strains and species, with the possible exception of timothy, there has been a considerable drop from the second to the fourth harvest year. The figures as a whole show how difficult it is to maintain sown species in good amount on a prepared sward.

Progressive Changes in Yield per Plant from the First to the Fourth Harvest Year.

The persistency data have shown that the progressive fall in yield of sown species from the first to the fourth harvest year is largely due to a considerable

* It is outside the scope of the present article to deal with the influences affecting delayed germination, or with the effects of delayed germination on the whole complicated question of competition.

drop in number of plants per unit of area in the later years. The figures in Table XXII, however, indicate that the fall in yield is due to an even greater extent to a marked reduction in yield per plant, while this reduction shows itself in a most striking manner as between the first and second harvest years, and is, therefore, more than a set off to any increase in the number of plants per unit of area that may occur during the same period.

TABLE XXII.—*To show the progressive changes in weight per plant for each of the sown species and strains in the hay crop from the first to the fourth harvest year. Weight in milligrammes per plant.*

Species and strain.	1st harvest year. 1924.	2nd harvest year. 1925.	4th harvest year. 1927.	4th harvest year when 1st harvest year = 100.
Perennial rye-grass commercial ..	4373	2310	809	18
Perennial rye-grass indigenous ..	3610	1570	505	14
Cocksfoot commercial	1310	424	178	14
Cocksfoot indigenous	1070	430	237	22
Tall fescue commercial	1350	970	388	21
Tall fescue indigenous	1220	1170	338	32
Timothy	2010	1650	573	28
Broad red clover	2820	1620	289	10
Average of all species and strains ..	2220	1268	440	..
Relative	100	58	19	..

The individual plants of perennial rye-grass have in each harvest year actually yielded more heavily than have such " large " grasses as cocksfoot and tall fescue. The high yield of indigenous cocksfoot in the fourth harvest year is now seen to be due not only to this strain retaining its persistency, but also to the fact that relatively it drops less than the commercial strain or than the rye-grasses in weight per plant. The figures in the table suggest that the poor yields from timothy in mixtures with other larger grasses is primarily due to poor establishment and poor persistency. The yields per plant have been fairly satisfactory in comparison with other species, and relatively the yields have been maintained from year to year better than in the case of cocksfoot or the rye-grasses. Broad red clover as well as dropping rapidly in persistency has also fallen in relative yield per plant by the fourth harvest year to a greater extent than any of the grasses.

When considering these yields per plant from year to year as indeed the yields of sown species as such, it must be remembered that the plots here under consideration have not been manured in any way subsequent to a uniform dressing of slag at seeding time. It will be shown in a subsequent bulletin that both the aggregate yields of sown species and the yields per plant are maintained at a more uniform level under appropriate manurial treatment.*

* In this connection it must also be remembered, however, that in practice it is quite a common thing not to manure hay producing leys for the explicit purpose of augmenting hay yields.

TABLE XXIII.—*To show the influence of perennial rye-grass sown respectively at 14 lb. and 4 lb. per acre and of tall fescue sown at 14 lb. per acre on the average weight per plant of cocksfoot, timothy and broad red clover considered as one unit, in the first, second and fourth harvest years. Weight in milligrammes per plant.*

Harvest year.	Perennial rye-grass		Tall fescue at 14 lb. per acre.
	at 14 lb. per acre.	at 4 lb. per acre.	
1st. 1924	682	1538	2467
2nd. 1925	1067	1040	1593
4th. 1927	215	288	500
Average for the three harvest years ..	655	955	1520

The weight per plant of the species is affected to a marked degree by the competitive influence of the more aggressive of the sown species: this is well shown by the figures in Table XXIII.

The average figures are very striking, and show conclusively the influence of heavy sowings of perennial rye-grass on the yielding ability per plant of other species contributing to the mixture, while even a sowing of 4 lb. of perennial rye-grass has had a greater effect than one of 14 lb. of tall fescue, although it must be remembered that the tall fescue did not establish itself well in the first harvest year.

E. 24: SEEDS MIXTURE EXPERIMENT WITH SIMPLE HAY MIXTURES: BRICK FIELD: SOWN 1922.

This experiment was primarily designed to test various nationalities and strains of red clover in simple mixtures, and from the clover point of view has been previously dealt with by Williams (24). The trial, however, deserves brief mention in the present connection.

The plots (1/100th acre) were sown on May 22nd in triplicate without a nurse crop. They were "put up" to hay before February, and cut at a normal date. Hay and aftermath data were obtained in the first and second harvest years, and hay data only in the third harvest year.

Discussion of Results.

A synopsis of the more important results and of the nature of the seeds mixtures is given in Table XXIIIA. As on the Barn Field, the indigenous cocksfoot and perennial rye-grass only represented preliminary collections and not pedigree strains, while the viability of the indigenous cocksfoot was poor and the establishment (although the seed rate was adjusted in sympathy with poor viability) not very satisfactory.

Having regard to the average relative yields of sown species only, it will be noted that as in the case of E. 19 and E. 40, the yields have fallen rapidly from the first to the third harvest year, while unsown species (chiefly bent and

TABLE XXIII A.—*Synopsis of the salient characteristics of the indigenous and commercial mixtures respectively and of the chief yield and other data obtained from E. 24 Brick Field. Yields in lb. green fodder per 1/100th acre plot.*

Mixture in lb. per acre.	Hay yields.			Aftermath yields.		Sum of hay and aftermath.	
	1923.	1924.	1925.	1923.	1924.	1923.	1924.
			I. *Yield data.*				
Indigenous perennial rye-grass 12; indigenous cocksfoot 8 and red clover 4	204	149	108	45	36	249	185
Commercial perennial rye-grass 12; commercial cocksfoot 8 and red clover 4	216	164	108	23	29	239	193
Average of indigenous and commercial mixtures	210	157	108	34	32	244	189
Relative yields based on sown species only ..	100	64	24	..	..	..	..
			II. *Percentage contribution of the two grass species and of weeds.*				
Perennial rye-grass	35	23	14	6	..	..	..
Cocksfoot	7	31	26	30	..	..	..
Unsown species (= weeds)	7	20	56	4	..	..	..

Yorkshire fog) have again gained rapidly on the ground—once more showing that without manuring for hay artificial swards very quickly deteriorate. In the case of this field as of Penglais Field and the Barn Field, the grazing during the non-hay producing period was never sufficiently hard, while the taking of two hay crops per annum for the first and second harvest years is not conducive to the establishment of a lasting sward.

Comparing the "indigenous" with the "commercial" mixtures it will be noted that in this trial in both the first and second harvest years the hay yields were in favour of the commercial, while by the third harvest year the crop produced by both mixtures was similar.*

The aftermath yields were very decidedly in favour of the indigenous mixtures—and this has been a striking feature of all the trials so far conducted with even the preliminary collections of indigenous strains. Thus, taking hay and aftermath together, the indigenous and commercial strains have yielded about equally over the two harvest years period.

The figures in Part II of the table serve once more to emphasize the very poor aftermathing ability of perennial rye-grass in marked contrast to the excellent behaviour of cocksfoot in this important respect.

In this trial, cocksfoot has contributed more abundantly than perennial rye-grass to the hay in both the second and third harvest years; it had also done so on Penglais Field (E. 19), but not nearly to the same extent. On Barn Field (E. 40) perennial rye-grass made very much the higher contribution in the second harvest year, and appreciably the higher in the third harvest year also.

E. 53: SEEDS MIXTURE EXPERIMENT WITH SIMPLE HAY MIXTURES: QUARRY FIELD: SOWN 1926.

This experiment was put down in connection with a field it was desired to grass out, and did not constitute one of the more critical trials at the Station. It has, however, given interesting first harvest year results, chiefly bearing on management, and deserves brief mention in connection with the trials now under review.

The mixtures were sown under oats on March 26th, 1926, following a sward sown only with Italian rye-grass and broad red clover, which had been left down for three years. The land was not, therefore, particularly clean, and the sown species were subject to competition with Yorkshire fog and bent grasses and other weeds from the outset. Reference to Table XXIV shows that in the first harvest year unsown species contributed more freely to the hay than either on Penglais Field (E. 19) or on the Barn Field (E. 40).

The chief interest of this experiment turns on the fact that the plots were grazed heavily by sheep off and on all through the autumn and winter of the seeding year, and in the spring of the first harvest year up till April 6th. The plots were cut for hay on June 10th. The plots, therefore, were given a comparatively short period for hay production, being cut decidedly early in relation to the date at which they were "put up"; they were consequently treated

* This fact will be referred to in a subsequent bulletin dealing with nationality trials conducted on the same field at the same time.

TABLE XXIV.—*To show* (1) *the seeds mixtures in lb. per acre*; (2) *the yields contributed by each sown species and by unsown species*; (3) *the percentage contribution to the total hay crop of each sown species and of unsown species*; (4) *the total yield per plot of the sown species*; *and* (5) *the aggregate yield per plot of sown and unsown species. Yields in lb. dry weight per* 1/10*th acre plot*: *first harvest year results*: *E.* 53: *Quarry Field.* 1927.

No.	Mixtures in lb. per acre.*	Species.																Total yield of sown species.	Aggregate yield of sown and unsown species.
		Italian rye-grass.		Perennial rye-grass.		Cocksfoot.		Timothy.		Meadow fescue.		Rough-stalked meadow grass.		Montgomery red clover.		White clover.		Weeds.			
		Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.	Yield.	Per cent.		
1	Mont. 4; white. 2; med. 2; Ital. 2; peren. 8; cock. 8; tim. 4	5.6	1.5	137.8	37.0	41.0	11.0	41.0	11.0	..	..	37.2	10.0	16.9	4.0	..	..	93.0	25.5	279.5	372.5
2	Mont. 4; white. 2; med. 2; Ital. 5; peren. 14 ..	78.7	21.0	206.4	55.0	..	..	..	..	..	..	41.2	11.0	7.5	2.0	..	..	41.2	11.0	333.8	375.0
3	Mont. 4; white. 2; med. 2; Ital. 5; cock. 14	185.6	47.0	..	..	110.6	28.0	..	..	..	..	67.2	17.0	13.8	3.5	..	..	17.8	4.5	377.2	395.0
4	Mont. 4; white. 2; med. 2; Ital. 5; tim. 14	170.2	46.0	..	..	..	..	88.8	24.0	..	..	44.4	12.0	25.9	7.0	..	..	40.7	11.0	329.3	370.0
5	Mont. 4; white. 2; med. 2; Ital. 5; med. f. 14 ..	153.0	39.0	..	..	..	..	..	..	57.0	14.5	45.1	11.5	21.6	5.5	2.0	0.5	113.8	29.0	278.7	392.5
6	Mont. 4; white. 2; med. 2; Ital. 10; peren. 14 ..	118.5	37.0	172.1	36.5	..	..	..	..	..	..	23.0	7.0	15.3	2.5	..	..	53.6	17.0	328.9	382.5
7	Mont 4; white 2; med. 2; Ital. 10; cock. 14	167.4	46.5	..	..	100.8	28.0	..	..	..	..	23.4	6.5	7.2	2.0	1.8	0.5	59.4	16.5	300.6	360.0
8	Mont. 4; white. 2; med. 2; Ital. 10; tim. 14	154.8	43.0	..	..	..	..	54.0	15.0	..	..	32.4	9.0	50.4	14.0	1.8	0.5	66.6	18.5	273.4	360.0
9	Mont. 4; white. 2; med. 2; Ital. 10; med. f. 14 ..	154.5	51.5	..	..	..	..	..	..	61.5	20.5	45.0	15.0	3.0	1.0	..	..	36.0	12.0	264.0	300.0
10	Mont. 4; white. 2; med. 14; Ital. 10	91.4	41.5	..	..	..	..	..	..	..	..	46.2	21.0	40.6	18.5	6.6	3.0	35.2	16.0	164.8	220.0
	Average yield and average contribution per species..	128.0	37.4	172.1	42.8	84.1	22.3	61.3	16.7	59.3	17.5	40.5	12.0	20.2	6.0	1.2	0.5	55.8	16.1	293.0	352.8

* Mont.=Montgomery extra late red clover. White.=wild white clover. Med.=rough-stalked meadow grass. Ital.=Italian rye-grass. Peren.=perennial rye-grass. Cock.=cocksfoot. Tim.=timothy. Med. f.=meadow fescue. Weeds=unsown species, largely bent grass and Yorkshire fog.

quite differently to those on Penglais Field and the Barn Field, which were "put up" decidedly early and cut at a normal date. The plots were 1/10th acre and duplicated in each case.

Discussion of Results.

The seeds mixtures employed and a synopsis of the chief results obtained are set out in Table XXIV. It will be noted that the mixtures were of a simple character: Montgomery extra-late red clover, wild white clover, rough-stalked meadow grass, and Italian rye-grass (at various rates) forming the basal ingredients of each mixture, and to these were added either perennial rye-grass, cocksfoot, timothy or meadow fescue, or more than one of these species.

Only just over two months were allowed for the production of a hay crop, and this period was a time of decided drought at Aberystwyth, the heavy rains of 1927 not beginning until June 16th. The average hay yield from all the plots none the less amounted to over $1\frac{1}{2}$ tons per acre in terms of weeds and sown species, or about $1\frac{1}{4}$ tons in terms of sown species only. This hay was intrinsically of very high quality, consisting of young, leafy and succulent grass and clover, while as a result of the early cutting the after-grass was abundant, and under intermittent grazing remained green and productive all through the winter.

Reference to the table reveals several striking results of considerable interest. In the first place it will be noted that the bulky extra-late Montgomery red clover contributed but slightly to the hay yield on all the plots. This was, of course, due to the earliness of the cutting, for Williams (23) has shown that having regard to both yield and quality the correct time to cut hay with this clover predominant is the last week in June or the first week in July, while the yield increases very rapidly from the middle to the end of June. In confirmation of the trials previously discussed, the fact remains that this clover has contributed more heavily where timothy has been associated with Italian rye-grass than where either cocksfoot or perennial rye-grass has been so associated; while in this trial there has not been very much difference between the influence of cocksfoot and perennial rye-grass; the former grass, however, having interfered with the clover quite as much as the latter.

The relatively high position taken by rough-stalked meadow grass on all the plots is interesting: on the average it contributed 12 per cent. to the hay crop. It follows, therefore, that this "bottom grass" when not set in strong competition with the larger grasses (which were kept well in check by the heavy spring grazing) is able to grow away rapidly and to take quite an important place in such late "put up" hay crops. Earlier investigations conducted by one of us had shown this grass to be often present in appreciable quantity, even in first year hay crops, and it would now seem that this can be expected on good soils when the grass is sown in sufficient quantity and the hay "put up" late. Wild white clover has only contributed to any appreciable extent when not competing with more than Italian rye-grass and rough-stalked meadow grass.

The vigour and rapidity of growth of Italian rye-grass is well exemplified, for although more heavily grazed than any other species and put up to hay on April 6th, it yet contributed abundantly to the hay crop. It will be seen that 5 lb. per acre under these conditions of heavy grazing have contributed as well to the hay as have 10 lb., but that 2 lb. have had a very slight influence on hay yield. It would appear to follow that 2 lb. of Italian rye-grass to the acre sown

in mixtures which are grazed into April serve wholly to give extra grazing and exercise a negligible influence on the competing hay species. Larger sowings, while giving more grazing, have the disadvantage of exercising an appreciable effect on the other species even when grazed heavily right through March and into April.

Despite the fact that 10 lb. of Italian rye-grass have yielded no more heavily in the hay than 5 lb., the larger sowing has yet had a greater reducing effect on the contribution of perennial rye-grass, cocksfoot, timothy, and rough-stalked meadow grass than has the smaller. This has probably been due to a certain smothering influence resulting from the larger sowings, which may have shown itself, as it often does, even under the oat crop. Confining attention to hay yields of sown species only, it will be seen that the simpler mixtures have given higher yields than the more complicated (represented by mixture 1). The heaviest crops have been obtained by the addition of either cocksfoot, perennial rye-grass or timothy to the basal sowings of Montgomery red clover, rough-stalked meadow grass and Italian rye-grass (5 lb. per acre) ; the addition of meadow fescue (peculiarly sensitive to competition with both rye-grasses) has not been nearly so efficacious.

SIMPLE GRAZING MIXTURES UNDER VARIOUS METHODS OF MANAGEMENT.

E. 36 : Spring Field : Sown 1923.

This experiment formed a part of numerous trials that have been in progress at Aberystwyth since 1915, bearing on the question of improving old swards by ploughing and immediately re-sowing on the upturned sod. The method of procedure has been fully discussed by Stapledon (16), and various results have been previously quoted by Stapledon and Davies (20), consequently it is unnecessary to give cultural and other details in the present connection. The trial under review has been reported upon to the end of the first harvest year,* and it is now intended to show the stages in the development of the sward to the end of the fourth harvest year.

The Seeds Mixtures and Methods of Grazing.

The field was divided into two areas, each of about 1½ acres ; on one area the strains used were indigenous and on the other commercial. As to species, the mixtures were identical ; they were as under :—

	Commercial lb. per acre.	*Indigenous lb. per acre.*
Italian rye-grass	6	6 (commercial)
Cocksfoot	13.5	13.5
Tall oat grass†	3.5	3.5
Tall fescue‡	1.4	2.2
Montgomery extra-late red clover ..	..	4.5
Chilian broad red clover	4.5	..
Wild white clover	..	1.0
White Dutch clover	1.0	..

* See Stapledon (16).

† Seed rate much too low, but determined by small supplies of indigenous strains available.

‡ Seed rate determined by supplies of indigenous seed available and commercial seed adjusted on the " real value " equivalent of the indigenous.

The small seed rates of the tall oat grass and tall fescue rendered the inclusion of these species of little significance, the mixtures, therefore, in effect being of the ultra-simple four species character.

With the exception of the small sub-plots " put up " to hay in the first and second harvest years, the experiment area was grazed throughout the whole four year duration of the experiment. Grazing started within three months of sowing (sowing date May 18th), and was continuous thereafter on a well regulated intermittent basis, periods of decidedly heavy grazing being followed by appropriate periods of rest. The grazing was by sheep for the most part, but the farm horses were given access to the field on several occasions.

Before the field was taken in hand it was dominated by bent grasses, and had the poorest carrying capacity. The flora consisted of nearly 70 per cent. bent grasses, Yorkshire fog, sweet vernal grass and fine-leaved fescues—grasses normally associated with derelict swards ; with about 11 per cent. miscellaneous weeds. Crested dogstail was present to an extent of about 10 per cent., and perennial rye-grass in traces. Wild white clover was present in patches over the field, on the best places never contributing more than 6 per cent. to the herbage ; bird's foot trefoil was also in slight evidence.

The area under the indigenous mixture was fenced off and grazed separately from the area under the commercial mixture.

A full record of the " sheep days " was kept for the period of the four years. In terms of Kerry Hill ewes of an average weight of about 130 lb., the carrying capacity of the " commercial " area worked out at 2.2 sheep per acre over the four year period, while that of the " indigenous " area worked out at 3.3 sheep per acre. The original carrying capacity of the field before ploughing may be taken as 1.1 Welsh mountain sheep (of decidedly less weight than the Kerry Hill) per acre.*

TABLE XXV.—*To show the percentage contribution of the different strains and species to the hay yields in the first and second harvest years.*

Species and strain.	1924.		1925.	
	Indigenous mixture.	Commercial mixture.	Indigenous mixture.	Commercial mixture.
Italian rye-grass (commercial) ..	38.1	38.0	17.1	15.6
Cocksfoot (indigenous)	4.4	..	21.1	..
Cocksfoot (commercial)	..	13.4	..	20.4
Tall oat grass (indigenous)	9.5	..	2.8	..
Tall oat grass (commercial)	..	4.6	..	4.6
Tall fescue (indigenous)	1.4	..	6.0	..
Tall fescue (commercial)	..	1.6	..	1.5
Montgomery red clover	30.7	..	12.8	..
Chilian red clover	..	17.5	..	1.8
Wild white clover	0.3	..	3.9	..
White Dutch clover	..	2.2	..	3.1
Yorkshire fog, bent, and other unsown species	15.5	22.6	35.9	52.9

* See Stapledon (16) and Pryse Howell (9).

TABLE XXVI.—*To show* (1) *the percentage contribution of the different sown species and strains in the first and second harvest years; and* (2) *the percentage contribution of all species in the fourth harvest year. Pasture plots: analyses by counts on the ground.*

Species and strain.	Indigenous mixture.			Commercial mixture.		
	1924	1925	1927	1924	1925	1927
Sown species.						
Italian rye-grass	33.6	19.7	..	29.4	21.7	..
Cocksfoot	29.1	52.5	32.0	38.6	66.5	4.0
Tall oat grass	0.4	5.5	1.3	0.4	9.2	trace
Tall fescue	..	5.8	1.0	..	1.5	1.7
Red clover	13.5	16.4	0.3	2.7	1.0	..
White clover	23.4	*	7.0	28.9	*	7.3
Unsown species.						
Perennial rye-grass			trace			0.3
Crested dogstail			3.7			6.3
Rough-stalked meadow grass			5.0			2.0
Smooth-stalked meadow grass			1.0			0.7
Fine-leaved fescue ..	†	†		†	†	
Bent ..						
Yorkshire fog ..			44.6			67.3
Sweet vernal grass ..						
Miscellaneous weeds ..			4.0			10.3

* Not counted and therefore not included in second harvest year analyses.
† Not included in first and second harvest year analyses.

DISCUSSION OF BOTANICAL RESULTS.

Complete separations were made of the hay sub-plots during the first and second harvest years, while on the main pasture plots counts were made of the sown species only in the first and second harvest years. No analyses were made in the third harvest year, but complete analyses (counts on lifted turfs) covering sown and unsown species were made in the fourth harvest year.

The results of the hay analyses are given in Table XXV.

The high contribution of Montgomery clover in both the first and second harvest years compared to Chilian clover is to be noted, while in competition with the Montgomery clover the indigenous cocksfoot has not done so well as the commercial in competition with Chilian clover. The most important point to note in the present connection is the extent to which bent grasses and other unsown species have gained re-entry. The significant fact is, however, that these species are far less prominent on the "indigenous" than on the "commercial" plots.

The results of the counts on the ground are given in Table XXVI.

During the first and second harvest years the commercial cocksfoot had done as well as the indigenous (but it must be remembered the commercial was set in competition with Chilian and not with Montgomery clover). By the fourth harvest year the contrast between the two cocksfoots was the outstanding feature of the trial—the Danish had ceased to contribute in quantity to the sward, while the indigenous was present to the extent of over 30 per cent. As a result the "indigenous" area consisted of but 48.6 per cent. of weeds and

of the grasses associated with deteriorated swards, while the "commercial" area had practically reverted to its original state with nearly 80 per cent. of such grasses and weeds.

The state of affairs relative to white clover is interesting, for in this case the inclusion of wild white clover had made no difference by the fourth harvest year. In the second harvest year the notes showed that white clover was much more abundant on the "indigenous" (wild white) area, but that volunteer wild white was gaining entry in considerable quantity on the "commercial" (white Dutch area)—the white clover on this latter area by the fourth harvest year was entirely due to the self establishment of the wild (or local) form. These data in comparison with those from other trials serve to show how difficult it is to assess beforehand in particular cases the precise and lasting benefits that may be expected from the inclusion of wild white clover even in simple grazing mixtures—the sowing in this case was, however, only 1 lb. per acre.

The botanical evidence as previously stated indicates that the indigenous mixture (chiefly by virtue of the success of the cocksfoot) up to the end of the fourth harvest year had given a sward vastly superior to the original turf, but the commercial mixture had almost completely reverted by the fourth year. The general character of the sward even on the commercial area was, however, much superior to the original turf—the growth was fresher and less tufted, being more palatable and of higher carrying capacity than that of the field before it was ploughed. The fact that the beneficial effect of ploughing and sowing on the upturned sod appears to last longer than the mere botanical analyses would seem to indicate has been noted in connection with previous trials, and has been alluded to by Stapledon and Davies (20) in earlier reports, and it is significant that the present and more critical results bear out those of the experiment started some years earlier.

E. 53 : The Bank : Pasture Mixture : Sown 1922.

This mixture was sown on a very shallow, stony soil on a steep bank. The field had been in inferior grass largely dominated by bent grasses for a large number of years. It was ploughed (one way) in 1920 and a crop of oats taken. In 1921 it was fallowed, but on account of the steepness of the hillside the cleaning operations were by no means thorough. The mixture was sown on May 8th, 1922, without a nurse crop. The field was grazed on the usual intermittent basis partly by horses and partly by sheep from about three months after sowing, and this was continued until the end of the fifth harvest year (1927). Sub-plots were "put up" for hay for four harvest years. Botanical analyses were made of the hay in the second and fourth harvest years, and of the sward (counts on the ground) in the second and fifth harvest years.

The essential character of the mixture (in lb. per acre) was as follows :— Indigenous perennial rye-grass 10 lb. ; a mixture of indigenous and New Zealand cocksfoot 20 lb. ; indigenous timothy 5 lb. ; commercial crested dogstail 2½ lb. ; Montgomery red clover 5 lb. ; wild white clover 2½ lb. : in addition, small quantities of tall oat grass and bird's foot trefoil, in amount, however, insufficient to influence the character of the sward.

Discussion of Results.

Since this trial was not set up on a critical basis, no control plot with commercial strains of the chief species instead of indigenous was available for

comparison—nor was wild white clover excluded on a control area. The result is, however, interesting as showing that on very poor ground and with very inadequate preparation a remarkably successful and lasting sward has been achieved. An important condition making for success was the heavy treading by sheep comparatively soon after sowing, this contributing to consolidation, which, owing to the steepness of the hillside, it has been impossible to achieve by resort to the roller. Had the field been sown under oats, this means of consolidation would have been impossible. The trial therefore affords striking evidence of the benefits of sowing under rape or without a nurse on steep and difficult fields.

The results of the various botanical analyses are shown in Table XXVII.

TABLE XXVII.—*To show the contribution of the various species* (1) *to the hay crop* (*on the sub-plots*) *in the second and fourth harvest years*; *and* (2) *to the sward* (*counts on the ground*) *in the second and fifth harvest years.*

Contributing species.	Results of hay analyses.		Results of pasture analyses.	
	2nd harvest year 1924.	4th harvest year 1926.	2nd harvest year 1924.	5th harvest year 1927.
Indigenous perennial rye-grass ..	10.0	5.6	15.6	4.1
Indigenous and New Zealand cocksfoot	20.7	29.9	19.9	26.5
Indigenous timothy	7.6	2.2	9.7	1.6
Crested dogstail	6.3	13.9	14.6	19.7
Montgomery red clover	30.4	1.9	7.5	0.3
Wild white clover	3.1	3.0	8.9	28.7
Other sown species	3.4	2.4	2.3	0.5
Unsown species, including bent, Yorkshire fog, and weeds	18.5	41.1	21.5	18.6

The outstandingly successful species have been cocksfoot (half indigenous and half New Zealand), crested dogstail, and wild white clover. The sward in the fifth harvest year contains an exceptionally small amount of bent grass and weeds for so poor a field with really considerable contributions from the cocksfoot, crested dogstail, and wild white clover. It is interesting to note that the hay and pasture analyses confirm each other by showing the altogether greater contribution of indigenous New Zealand cocksfoot than of indigenous perennial rye-grass subsequent to the second harvest year. It is also to be noted that crested dogstail immediately made itself felt, contributing to the hay crop appreciably in the second harvest year, and actually out-yielding the perennial rye-grass in the fourth harvest year, and being over four times as plentiful as the rye-grass in the sward in the fifth harvest year. This behaviour of crested dogstail is in agreement with that previously shown on the pasture plots on Penglais Field (E. 19), and once more proves what a valuable grazing grass this species is on poor soils not well suited to perennial rye-grass.*

The success of the indigenous cocksfoot (although diluted with New Zealand†) is in support of the results from the Barn Field (E. 40), and tends to

* The field was always run over with the mowing machine in June, and this prevented the dogstail running to "bents" and maintained it in a leafy and succulent condition.

† New Zealand cocksfoot is, of course, much closer to indigenous in its characteristics than to Danish commercial.

confirm a considerable body of evidence suggesting that pedigree indigenous strains are likely to prove of immense grazing value on poor land. The indigenous timothy has held the ground well considering the extent of the competition with cocksfoot. It will be noted that Montgomery clover had held the sward in traces to the end of the fifth year. The high percentage of wild white clover in the sward is strongly suggestive of benefits resulting from sowing as much as 2½ lb. of the seed ; for at most the original sward on the field would have been unlikely to have contained more than 5 to 6 per cent. of the locally volunteering white clover. This trial then represents a remarkable success following the use of a simple mixture supported by well controlled heavy and intermittent grazing.

E. 37 : SEEDS MIXTURE EXPERIMENT WITH SIMPLE HAY AND PASTURE MIXTURES : BARN FIELD : SOWN 1923.

Two mixtures were sown on replicated 1/400th acre plots. The one mixture was of the simple pasture type and consisted of indigenous perennial rye-grass 8 lb. ; crested dogstail 6 lb. ; rough-stalked meadow grass 2 lb. ; Montgomery red clover 4 lb. ; and wild white clover 2 lb. The other mixture was of a simple hay type and consisted of Italian rye-grass 2 lb. ; commercial perennial rye-grass 6 lb. ; commercial cocksfoot 8 lb. ; timothy 4 lb. ; English late flowering red clover 4 lb. ; and wild white clover ½ lb. The field had been in permanent pasture for a number of years. It was ploughed in 1922 for a crop of oats and after further preparation the seeds mixtures were sown in 1923.

The soil was a rather heavy clay-loam, and the fertility was high. The preparation had been good, but *Ranunculus repens* and *Bellis perennis* made immediate and rapid re-entry. Yorkshire fog and bent grasses were not in strong evidence and did not here at any stage contribute largely to the sown swards.

The plots were treated in various ways, some as hay, some as pasture. The results here given are based on the average of all the plots, and are considered in the present connection only from the point of view of the relative persistency of the different species and strains. Counts were made on the ground during the first, second, fourth, and fifth harvest years. The results of the counts are given in Table XXVIII.

The chief points of interest are as follows :—

The indigenous perennial rye-grass has been more persistent than the commercial, as shown by the fourth and fifth harvest year results, although in this trial the difference in favour of the indigenous has not been nearly as great as in other trials previously discussed. In the hay mixture the persistency of both commercial cocksfoot and timothy into the fourth and fifth harvest years has been greater than in the case of other trials under review. In this trial the persistency of the English late flowering red clover has shown to as good advantage as that of the extra-late Montgomery ; while alsike clover has not here persisted in any quantity into the second harvest year. The relatively good persistency of cocksfoot, timothy, and English late flowering red clover is to be attributed to the higher fertility of this field than of other fields on which the trials under review have been conducted.

The place taken by crested dogstail in the pasture mixture is in accord with all previous trials, and in the fourth and fifth harvest years this species on the plots where it was included is making a higher contribution than any other sown

TABLE XXVIII.—*To show the percentage contribution of the various species on the basis of counts on the ground in the case of a simple pasture and simple hay mixture for four of the five harvest years* 1924—1928.

Species in the mixtures.	1st harvest year. 1924.		2nd harvest year. 1925.		4th harvest year. 1927.		5th harvest year. 1928.	
	Pasture mixture.	Hay mixture.	Pasture mixture.	Hay mixture.	Pasture mixture.	Hay mixture.	Pasture mixture.	Hay mixture.
Italian rye-grass	..	10.3	..	5.9	..	2.4	..	0.3
Perennial rye-grass	32.5	20.2	18.6	15.2	27.2	21.7	13.7	10.9
Cocksfoot	..	21.0	..	24.9	..	25.3	..	10.9
Timothy	..	11.3	..	13.1	..	24.1	..	7.0
Crested dogstail	18.3	..	23.8	..	42.1	..	21.6	..
Rough-stalked meadow grass	16.8	..	14.8	..	6.4	4.6*	8.9	..
Late flowering red clover	13.4	15.6	5.9	9.4	6.6	5.6	3.1	3.1
Alsike clover	..	7.9	..	1.1	..	..	..	..
Wild white clover	6.5	3.2	11.8	4.9	17.5	16.3	10.5	10.7
Yorkshire fog	†	†	†	†	†	†	4.1	5.7
Bent grasses	†	†	†	†	†	†	2.0	2.5
Other weeds‡	12.4	10.6	25.0	25.4	†	†	35.9	48.7§

* Voluntary appearance of indigenous strains.
† Not counted and not included in the analyses.
‡ Chiefly *Ranunculus repens* and *Bellis perennis*.
§ Includes some rough-stalked meadow grass, here counted with "weeds"—considered as unsown species.

species in the experiment. Rough-stalked-meadow grass has here maintained itself well, but not nearly as well as the dogstail—on the plots where sown its contribution has been in excess of that made by voluntary establishment on other plots. The 2 lb. of wild white clover in the pasture mixture compared to ½ lb. in the hay mixture showed to considerable advantage in the first and second harvest years, but by the fourth and fifth harvest years the clover contribution was practically the same from both rates of seeding.

At the end stage, weeds were in less evidence in the " pasture " than in the " hay " mixture, chiefly as the result of the contribution made by crested dogstail and rough-stalked meadow grass in the former mixture.

One series of comparable and adjoining plots was cut each harvest year for hay and aftermath, while another was cut at regular intervals during each harvest year with the garden mowing machine. The cutting was drastic in the first harvest year (8 times) and less drastic in subsequent years (4 or 5 times). It is interesting to compare the final persistency of the species and strains under the two treatments as revealed by counts made in the fifth harvest year. The results are given in Table XXIX.

TABLE XXIX.—*To compare the relative persistency of the different species and strains (counts on the ground) in the fifth harvest year on plots cut each year for hay and aftermath with those cut each year at repeated intervals with the garden mowing machine. Percentage frequency,* 1928.

Species and strain.	" Pasture " mixture.		" Hay " mixture.	
	Hay each year.	Repeated cuts each year.	Hay each year.	Repeated cuts each year.
Italian rye-grass	..	..	0.3	0.8
Perennial rye-grass	11.4	9.1	11.5	6.8
Cocksfoot	..	..	7.5	3.2
Timothy	..	..	13.4	8.1
Crested dogstail	21.3	22.0	..	..
Rough-stalked meadow grass	10.8	2.6	..	..
Late flowering red clover	4.7	1.6	2.5	1.4
Wild white clover	7.9	10.5	10.6	12.5
Yorkshire fog	7.9	0.8	3.4	5.7
Bent grasses	2.5	2.1	2.5	1.6
Other weeds*	33.3	51.3	47.8	60.0

* Chiefly *Ranunculus repens* and *Bellis perennis.*

In both the " pasture " and " hay " plots, perennial rye-grass and late flowering red clover contributed most highly on the hay-each-year plots, and on the plots (the " hay " mixture) where cocksfoot and timothy were included the same is true of these species. Crested dogstail made an equally good contribution on the hay-each-year and mowing machine plots ; rough-stalked meadow grass, although an excellent pasture grass, did much better, however, on the former plots. Wild white clover withstood the mowing machine treatment perfectly well, and on the average made the highest contribution on these plots.

Ranunculus repens and *Bellis perennis* made headway relative to the sown species on the repeatedly cut plots, where they contributed in greater quantity than on the hay-each-year plots. On the average, Yorkshire fog would seem to have been rather favoured by the hay conditions, while the bent grasses were not differentially affected.

E. 52 : I, II, AND VI. VARIOUS EXPERIMENTS WITH SIMPLE PASTURE MIXTURES ON LANE FIELD AND CWM FIELD : SOWN 1924.

The more important of these trials were laid out in duplicate on two fields—the Lane Field and Cwm Field. The mixtures were of extreme simplicity and designed largely to test the rival merits of indigenous and commercial strains of grasses for the formation of pastures.

The soil on the Lane Field was a heavy clay, and the field was not well drained ; it had been in grass for a number of years until it was ploughed and sown to oats.

The seeds mixtures on this field were sown on May 29th, 1924, without a nurse crop, and with the exception of a few sub-plots cut for hay in the first harvest year the developing sward was treated as pasture throughout the experiment.

The soil on the Cwm Field was a medium to light loam and was well drained. The field had, however, been neglected for a large number of years and was in a very poor state of fertility, showing a high lime requirement. It was ploughed from an inferior sward consisting almost wholly of Yorkshire fog, creeping soft grass (*Holcus mollis*), and bent grasses with some fine-leaved fescues.

The experimental mixtures were sown on May 15th, 1924, under an oat crop, and after the harvesting of the oats the field was treated as a pasture during the whole period of the experiment.

Cwm Field had never been properly cleaned before sowing the trials, and the bent grasses, Yorkshire fog, and *Holcus mollis* immediately gained re-entry on the new swards. Lane Field was decidedly cleaner, but on this field also the bent grasses (in this case *Agrostis alba* and *A. vulgaris*), Yorkshire fog, and the little rush, *Juncus bufonius*, with *Scirpus setacea* were in strong evidence on the plots even in the first harvest year.

THE EXPERIMENTAL MIXTURES : BROADCAST TRIALS.

Three basal mixtures were employed as under in lb. per acre :—

	I.	II.	III.
Italian rye-grass	4	4	..
Montgomery red clover	4	..	..
Wild white clover	2	2	2

To each of the above mixtures 14 lb. of one other grass species were added. In the case of several of the grasses two strains (commercial and indigenous) were employed—each strain being regarded as a separate unit and having a series of the three mixtures to itself. The species and strains added to the basal mixtures were as follows :—Indigenous and commercial strains of perennial rye-grass, cocksfoot, timothy, tall oat grass, and tall fescue ; commercial strains of meadow fescue, red fescue (Chewing's), crested dogstail, rough-stalked meadow grass, and sweet vernal grass.

Therefore 45 mixtures were brought under trial, while plots which received no seeding were included as controls. The plots were 1/20th acre and were duplicated on each field.

Discussion of Results: Delayed Establishment.

These trials were not intended to be critical, and were designed merely for observation, consequently no counts were made during the seeding, first and second harvest years. Turfs were, however, lifted and accurate counts made in the third harvest year. The "takes" were decidedly poor on both fields—on Lane Field chiefly due to the poorness of the tilth and the wetness of the ground, and on Cwm Field due to the lodging of the oats as the result of the wet season and to immediate re-colonization by unsown species. The grazing was at all times adequate on the established sward on Lane Field, but was wholly insufficient on Cwm Field* during the autumn of the seeding year and all through the first harvest year.

The routine notes taken on Cwm Field revealed an exceptionally interesting state of affairs. The bent grasses and the two species of *Holcus* entered in quantity from the very outset, and were in marked evidence in the "seeds" as soon as the oats were harvested. Examination of the plots in the autumn of the seeding year suggested an almost complete failure of take—indeed in the case of wild white clover, rough-stalked meadow grass, and crested dogstail the number of established plants appeared to be negligible, and it was only the rye-grasses that had made anything approaching a satisfactory stand.

A fairly heavy mat of bent and Yorkshire fog foggage was allowed to stand on the plots right through the winter and into the first harvest year: in the spring this foggage was unpalatable to sheep, and as the late summer approached, the field became one mass of bent and Yorkshire fog which the sheep grazed to only a slight extent. At this period it was concluded that the trial had been a complete failure and that the sown species had been totally unable to establish themselves, and it was decided to plough the field. A little later the mowing machine was run over the sward preliminary to ploughing, and it was then grazed hard with the Station flock of sheep for some weeks. Towards the late autumn slight signs of improvement were observed on the field, and it was soon apparent that the sown species had by no means been a complete failure—cocksfoot began to be in evidence on the plots where it was sown, while the finer grasses and wild white clover were undoubtedly establishing themselves to some slight extent, and for the first time the field began to have the appearance of having been sown out in plots. It was therefore decided not to plough, but to hold as many sheep as possible on the field all through the winter. By the spring of the second harvest year the field had undergone an unmistakable change and tolerably good swards of sown species had begun to develop on all the plots. Hard grazing supported by the mowing machine was continued throughout the spring and summer; by the autumn the field had undergone a complete transformation and there was now not the least doubt as to the establishment of the sown species. This treatment, grazing and the mowing machine, was repeated in the third year up to the time the plots were sampled for analyses.

* The field had been recently taken over by the Station, and was inadequately fenced and somewhat remote.

The results here quoted are the more interesting because they afford complete confirmation of the critical data that have been collected at the Station relative to the influence of the phenomenon of delayed germination as applied to the question of putting land down to grass.

It is unfortunate that counts had not been made at all stages throughout the experiment, but there was no doubt as to the initial failure of "take." The fact that recovery had been chiefly due to the seed sown and not to volunteer colonization by local strains was obvious on comparing the plots one with the other in the third harvest year. The final proof, however, was given by comparing the no-seeding plots with the mixture plots. The following figures in respect of those species which were most likely to have made abundant volunteer entry alike on the sown and unsown plots speak for themselves, and the balance in favour of the sown plots permits of no other explanation than that of belated establishment resulting from the seed sown :—

	Sown plots.	*Unsown plots.*
Wild white clover	22.8	12.5
Red fescue	47.8	7.5
Crested dogstail	40.0	trace.
Rough-stalked meadow grass	45.0	2.5
Sweet vernal grass	3.7	trace.

The only evidence that is lacking is the precise stage at which strong germination and establishment commenced, that is to say, precisely how long the seeds were dormant before germinating, though the notes and the general evidence combine to suggest that the seeds were chiefly vitalized by the removal of the foggage by the mowing machine and subsequent heavy grazing.

The figures also show that in this case the sowing of as much as 2 lb. per acre of wild white clover had been fully justified by the excess of this clover on the sown over the unsown plots. The large seedings of crested dogstail, rough-stalked meadow grass, and Chewing's fescue had also been responsible for the successful though belated introduction of these plants in really telling quantity—in this case not even rough-stalked meadow grass having made a strong volunteer appearance.

The Various Species and Strains of Sown Species Compared.

The species and strains behaved in a very similar manner on both fields, so that it is only necessary to consider average results. Owing to the failure of initial establishment no great difference showed itself as between the plots sown with the three different basal mixtures, consequently the results here given are the average of the three series. The data presented in Table XXX are based on counts made in the third harvest year, and it must be remembered that each experimental grass was only sown in competition with the elements of the basal mixture, namely, with Italian rye-grass, Montgomery red clover, and wild white clover—four species being the maximum number included in any one mixture.

As in the previous experiments, the smaller "bottom" grasses—Chewing's fescue, crested dogstail, and rough-stalked meadow grass—have contributed more highly than any of the larger grasses to the sward of the third harvest year. Sweet vernal grass has, however, not established itself well from seeding. Of the larger grasses, tall fescue has been the most successful in persistency, which

TABLE XXX.—*To show the behaviour of the several species and strains in the third harvest year. The figures are the average of counts made on both Lane Field and Cwm Field.* 1927.

Species.	Indigenous and commercial compared when both included.		Average of indigenous and commercial or commercial only
	Indigenous.	Commercial.	
Italian rye-grass	..	..	1.3
Perennial rye-grass	25.6	15.0	20.3
Cocksfoot	23.4	12.2	17.8
Timothy	22.9	8.7	15.8
Tall oat grass	2.0	0.1	1.1
Tall fescue	36.2	14.1	25.2
Average	22.0	10.0	..
Meadow fescue	..	..	5.6
Chewing's fescue	..	..	41.9
Crested dogstail	..	..	35.9
Rough-stalked meadow grass	..	..	41.3
Sweet vernal grass	..	..	2.9
Montgomery red clover	..	..	0.1
Wild white clover	..	..	21.5
Unsown species*	..	..	61.0
Bare ground†	..	..	12.5

* Chiefly Yorkshire fog (and on Cwm Field *Holcus mollis*) and the bent grasses.
† The bare ground was estimated separately and independently of the various species.

is in keeping with other results, and shows that this is a species which when once established is undoubtedly persistent. The grass is, however, not very palatable under West Wales conditions, and its persistency no doubt owes much to this fact.

The difference in persistency between the indigenous and commercial strains is very striking, and is again markedly in favour of the former—22 per cent. from the average of the species concerned compared with 10 per cent. The position taken by indigenous timothy is particularly noteworthy and is in confirmation of numerous trials with pure plots, all of which appear to indicate that the best indigenous strains of this species are destined to be of real value as pasture plants—a somewhat unexpected result which may render necessary an adjustment in current views as to the uses of timothy. In this trial, unlike E. 40 (Barn Field), indigenous tall fescue has shown to decidedly better advantage than commercial Rhenish.

The contribution of unsown species is high, and this was to be expected having regard to the condition of the field and the unsatisfactory early management to which it was subjected.

Drill Trials.

Earlier trials at the Station had suggested that it might prove an economical means of establishing simple seeds mixtures to sow the grass and clover species in alternate drills.

In the experiment under review wild white clover and Italian rye-grass were sown in this manner on plots at various rates. Owing to the delayed germina-

TABLE XXXI.—*To show the percentage frequency of Italian rye-grass, wild white clover, and unsown species in the third harvest year when Italian rye-grass and wild white clover were sown in alternate drills.* 1927.

Mixture.	Italian rye-grass.	Wild white clover.	Unsown species.
Italian rye-grass 10 lb. ; wild white clover ½ lb. ..	3.7	31.3	65.0
Italian rye-grass 20 lb. ; wild white clover ½ lb. ..	10.3	36.0	53.7
Average	*7.0*	*33.6*	*59.3*
Italian rye-grass 10 lb. ; wild white clover 1 lb. ..	6.3	28.7	65.0
Italian rye-grass 20 lb. ; wild white clover 1 lb. ..	7.7	35.3	57.0
Average	*7.0*	*32.0*	*61.0*
Italian rye-grass 10 lb. ; wild white clover 2 lb. ..	5.3	26.7	68.0
Italian rye-grass 20 lb. ; wild white clover 2 lb. ..	5.3	40.3	54.4
Average	*5.3*	*33.5*	*61.2*
Italian rye-grass 10 lb. ; wild white clover 4 lb. ..	5.3	44.6	50.7
Italian rye-grass 20 lb. ; wild white clover 4 lb. ..	1.7	36.3	62.0
Average	*3.5*	*40.1*	*56.3*
Average of all plots	5.7	34.8	59.4

tion and delayed growth previously mentioned the trial was not a fair one, but the data presented in Table XXXI are sufficiently interesting to deserve brief mention.

From this ultra simple mixture sown in drills on land in an unsatisfactory condition the contribution of wild white clover to the sward was over 10 per cent. greater than on the 4 species broadcast plots, while the percentage of unsown species, chiefly Yorkshire fog and the bent grasses, was actually slightly less on the simple drill plots than on the broadcast plots. The result is thus in marked confirmation of earlier trials conducted at Cilmery, and goes to show that wild white clover can be economically established by this means even on fields in poor condition.

At the end stage (third harvest year) it was only the 4 lb. seeding of wild white clover that showed any material advantage over the lesser seedings—this large seeding also being associated with a lower contribution of unsown species. This result is in keeping with other trials, which seem to suggest that the full benefits of larger sowings of wild white clover will only be apparent when satisfactory conditions for establishment and early development are assured.

E. 61 : SIMPLE MIXTURES (CHIEFLY DESIGNED FOR GRAZING) IN THE MAIN PUT DOWN UNDER EXCELLENT CONDITIONS. VARIOUS CENTRES : SOWN 1925.

Crosswood.

A number of simple mixtures were put down at this centre. The plots were usually 1/10th acre in triplicate ; in certain cases the mixtures were sown on two different fields. The plots were sown without a nurse crop on well cleaned land in good heart, and were grazed on an intermittent basis from the outset.

WHITE DUTCH CLOVER *versus* WILD WHITE CLOVER.

Three contrasting mixtures were prepared: the first contained 4 lb. of white Dutch clover and no rough-stalked meadow grass; the second contained 2 lb. of wild white clover and 1 lb. of rough-stalked meadow grass; and the third, 2 lb. of wild white clover and 2 lb. of rough-stalked meadow grass. Otherwise the mixtures were essentially the same, the basal ingredients being commercial strains of perennial rye-grass, cocksfoot, timothy, and late flowering red clover.

The following results based on counts made in the second harvest year are instructive:—

	Per cent. contribution of			
	White clover.	Rough-stalked meadow grass.	Weeds.	Bare ground.
Plots sown with mixtures including white Dutch clover	12.0	..	22.7*	30.5*
Plots sown with mixtures including wild white clover	27.6	..	3.2†	10.7†
Plots sown with mixtures including 1 lb. rough-stalked meadow grass	..	20.7	..	..
Plots sown with mixtures including 2 lb. rough-stalked meadow grass	..	38.0	..	..
Plots sown with mixtures without rough-stalked meadow grass ..	..	4.2	..	..

These data are in full accord with earlier results reported from the Station, and show that when excellent takes are achieved from the outset, and when the grazing is well regulated, wild white clover far surpasses white Dutch even as soon as the second harvest year, while the association of abundance of wild white with rough-stalked meadow grass tends to form a sole to the sward rapidly and so to eliminate weeds and bare ground. Rough-stalked meadow grass here, as it so often does, has succeeded in direct proportion to the seed rate, and the sowing has greatly hastened the useful contribution of this valuable species to the sward.

INDIGENOUS *versus* COMMERCIAL STRAINS.

In a series of mixtures otherwise similar, indigenous and commercial strains of cocksfoot, timothy, and perennial rye-grass were compared. The takes were excellent and the swards treated wholly as pastures. In the second harvest year the following figures (based on counts on the ground) were obtained:

Cocksfoot	indigenous	contributed	27.0	per cent.	to the	sward.
,,	commercial	,,	21.0	,,	,,	,,
Timothy	indigenous	,,	12.5	,,	,,	,,
,,	commercial	,,	6.0	,,	,,	,,
Perennial rye-grass	indigenous	,,	45.4	,,	,,	,,
,,	commercial	,,	35.8	,,	,,	,,

Here, as soon as the second harvest year under grazing conditions, the advantage was already markedly in favour of the indigenous strains, and this very particularly so in the case of timothy.

* The figures for plots without rough-stalked meadow grass.
† The figures for plots also containing 1 lb. of rough-stalked meadow grass.

Results from Simple Mixtures.

At this centre some of the most striking results have been obtained with pasture mixtures of extreme simplicity. The best example is that of a mixture consisting of indigenous perennial rye-grass (cleanings *ex* wild white clover) 14 lb.; rough-stalked meadow grass 2 lb., and wild white clover 2 lb., to which on some plots were added 4—6 lb. of Montgomery red clover.

In the second harvest year the swards from this mixture were approximately as under on two separate fields :—

	Deep rich loam.	*Sharper shallower loam.*
Perennial rye-grass	42.0	46.0
Rough-stalked meadow grass ..	25.0	21.0
Wild white clover	24.0	17.0
Weeds	2.0	13.0
Bare ground	7.0	3.0

The analyses show that when simple mixtures of this type are put down on clean land in good heart and grazed from the outset surprisingly weedless and dense swards can be achieved. The sward on the deep rich loam is remarkable for its unique freedom from weeds—bent and Yorkshire fog being almost entirely absent. It should be pointed out that the mixture on the deep loam was sown without a nurse crop, while that on the shallower soil was sown under oats, and there is no doubt that this fact has contributed to the paucity of weeds and greater excess of clover on the former field. The contrast with the plots on Penglais and other fields previously discussed is very great, for on many of these the contribution of unsown species, chiefly Yorkshire fog and bent grasses, even by the second year exceeded 20 per cent.

Nationality Trial with Red Clover at 17 Centres.

This trial was sown in 1925 in duplicated 1/20th acre plots. The standard mixture employed was a modified "Cockle Park" and consisted of Italian rye-grass 2 lb.; indigenous perennial rye-grass 6 lb.; commercial cocksfoot 8 lb.; commercial timothy 4 lb.; rough-stalked meadow grass 2 lb.; the particular nationality of red clover 6 lb., and wild white clover 1 lb. The nationalities and regional strains of red clover are shown in Table XXXIII. The 17 centres gave a considerable range of soil fertility and of elevation. At all the centres from which data were obtained hay was taken in the first and second harvest years, but at all centres the fields were "put up" to hay late, grazing being continued late into the spring.

The results may be considered from the point of view of the behaviour of the mixture as a whole, and with reference to the various nationalities and strains of red clover.

The Behaviour of the Mixture.

The several centres were classified into three fertility classes, based on the estimated yields of the hay crops.*

The results may be usefully considered from this point of view, and are given in Table XXXII.

* Yield data were not obtained, but the centres were all visited at hay harvest and samples carefully taken for botanical analyses.

TABLE XXXII.—*To compare the percentage productivity (based on botanical separations of the hay) of the hay from the "high fertility," "intermediate fertility," and "low fertility" centres in the first and second harvest years.*

Species.	First harvest year 1926.			Second harvest year 1927.		
	High fertility centres.	Intermediate fertility centres.	Low fertility centres.	High fertility centres.	Intermediate fertility centres.	Low fertility centres.
Italian rye-grass ..	15.7	15.7	19.3	3.4	2.4	0.9
Perennial rye-grass (indigenous) ..	25.1	26.0	28.5	47.4	33.9	39.6
Cocksfoot	4.9	5.3	5.6	11.4	13.9	8.6
Timothy	4.1	6.7	4.5	7.1	7.9	6.4
Rough-stalked meadow grass	5.1	5.5	8.0	13.6	16.1	7.4
Red clover*	41.8	34.0	25.6	8.1	9.3	9.5
Wild white clover ..	3.9	4.2	1.7	3.2	5.1	7.0
Unsown species ..	2.5	4.6	7.6	5.3	12.1	20.2

* Average of the several nationalities and strains.

In considering the results it must be remembered that no regard has been paid to yield as such or to ground analyses, but only to the proportionate contribution of the species to the hay. With reference to the behaviour of the mixture as a whole, it will be seen that the indigenous perennial rye-grass has carried well into the second year, while the cocksfoot and timothy have done so comparatively well, largely as a result of the hindered competition with Italian rye-grass consequent upon the fact that at the majority of the centres the hay was "put up" late. Rough-stalked meadow grass has in this trial once more shown itself able to contribute appreciably to the first year's hay crop and quite abundantly to that of the second year. The results from 1 lb. of wild white clover have been satisfactory having regard to the fact that hay was taken in both harvest years.

Comparing the fertility classes, it will be noted that in the first harvest year perennial rye-grass had contributed in slightly larger measure at the low fertility centres than at the high fertility centres. This would probably be due to its relatively good capacity for soil establishment under adverse conditions. Red clover, on the other hand, has shown to very decidedly better advantage at the high fertility centres, and on the average white clover has behaved similarly—the clovers are, however, more susceptible to "establishment" conditions than are the rye-grasses. Even in the first harvest year, weeds are decidedly more plentiful at the low fertility centres, and by the second harvest year the difference between the three classes is very well marked, the high fertility class being still remarkably free from weeds. By the second harvest year perennial rye-grass, an undoubtedly high fertility demander, shows to the best relative advantage at the high fertility centres, and this is even more markedly so in the case of rough-stalked meadow grass, also a demander of reasonably high fertility. The position taken by the red clovers has now levelled up in respect of the fertility classes; this would be largely due to the

fact that at the low fertility centres the clover would not have been subjected to the same competition with grasses as at the high fertility centres. White clover has evidently been able to benefit by the reduced competition with shade-giving grasses at the low fertility centres, and by the second harvest year has more than made up for its relatively poor position in the first harvest year. The figures for unsown species (largely Yorkshire fog, sweet vernal grass, bent grasses, and yellow suckling clover) are very interesting, and show the marked influence of fertility on the re-entry of unsown species, this being by far the most rapid at the low fertility centres.

The Nationalities and Strains of Red Clover.

The average results from all the centres are brought together in Table XXXIII. Here again yield as such has not been considered, and the data are based only on the contribution of each strain to the hay crop.

TABLE XXXIII.—*To show* (1) *the average contribution of the several nationalities and strains of red clover to the hay crop in the first and second harvest years (average of all centres) ; and* (2) *the relative position taken by the different clovers with Cotswold late flowering red clover placed at* 100.

Nationality or strain of red clover.	1st harvest year 1926.		2nd harvest year 1927.	
	Per cent. contribution to the hay.	Relative with Cotswold late flowering red at 100.	Per cent. contribution to the hay.	Relative with Cotswold late flowering red at 100.
Early red clovers.				
English broad red ..	25	48	2.1	15
Chilian broad red ..	26	50	1.4	10
Intermediate red clovers.				
Vale of Clwyd	34	65	5.3	39
Late red clovers.				
Cotswold late flowering ..	52	100	13.7	100
Swedish late	28	54	5.2	38
American mammoth ..	48	86	8.7	64
Extra-late red clovers.				
Montgomery red	43	83	17.8	130
Cornish marl	33	64	10.1	74
Wild red clover.				
Wild red	32	62	16.3	119

The results from these trials at 17 centres are in the main entirely confirmatory of the extensive tests conducted by Williams (24) over a number of years at the Station. The late and extra-late varieties have shown themselves vastly superior to the earlier, not only in the second harvest year, but also in the first harvest year. Montgomery clover has fully substantiated the position accorded to it by the earlier trials : the results from Cornish marl have not been so satisfactory—the seed sample employed was, however, poor, and at no centre

was the take sufficiently good to permit of a fair comparison. In these trials, Swedish late has not done as well as Williams's results would have led one to expect. This may have been due to some special defect in the strain actually employed: the fact remains, however, that at the higher elevations in particular the plots sown with this strain gave disappointing results. The most interesting results are those given by wild red clover, which on the average of all the centres in the second harvest year stands second only to Montgomery red. The position taken by this strain has been largely due to the relative excellence of its behaviour at the high elevation and low fertility centres. The strain used represented one of the most promising wild reds so far under test at the Station, and the evidence therefore indicates that the best strains of this variety may have a real value for use under conditions of poor fertility—a greater value indeed than the earlier tests, conducted almost wholly at the Station, would have seemed to suggest.

TRIALS WITH SIMPLE MIXTURES CROSS-SOWN ON VARIOUS NATIONALITIES OF THE RED CLOVER AT SIX CENTRES.

This trial was sown in 1925 at six carefully selected centres representing different soil classes and elevations. The red clovers were the same as those used in the trial just discussed (6 lb. per strain). The nine mixtures employed for cross-sowing over the clover nationalities were as follows:—

(1) The modified "Cockle Park" employed in the previous experiment and

(2) Italian rye-grass 4 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., perennial rye-grass 14 lb.

(3) Italian rye-grass 4 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., meadow fescue 14 lb.

(4) Italian rye-grass 4 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., cocksfoot 14 lb.

(5) Italian rye-grass 4 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., timothy 14 lb.

(6) Italian rye-grass 12 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., perennial rye-grass 14 lb.

(7) Italian rye-grass 12 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., meadow fescue 14 lb.

(8) Italian rye-grass 12 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., cocksfoot 14 lb.

(9) Italian rye-grass 12 lb., rough-stalked meadow grass 2 lb., wild white clover 1 lb., timothy 14 lb.

In the case of mixtures (2)—(9) each was in effect a five-species mixture, consisting of three grass species and wild white clover with the particular red clover upon which these four species were cross-sown. A strip was also left at the end of each clover section without the addition of the four species mixtures—this constituted the "clover only" plots.

At one centre a "farmers" mixture (mixture 10) consisting of Italian rye-grass 6 lb., commercial perennial rye-grass 10 lb., cocksfoot 6 lb., timothy 8 lb., and late flowering red clover 6 lb. was also available for comparison.

At all centres the fields were clean and the seeds put down under good conditions, excellent " takes " being achieved. Hay was taken at most centres in both harvest years, but the fields were " put up " late and cut in good time—the autumn, winter, and early spring grazing was decidedly on the heavy side, particularly so at some of the centres.

The results can best be considered by dealing for the most part with those obtained at two contrasting centres, and it will be convenient in the present connection to concentrate attention upon certain definite points.

The Various Mixtures Compared.

A complete comparison of the results obtained with the various mixtures is made in Table XXXIV (on the basis of ground analyses). These particular results refer to lowland centres only (at one of which the " farmers " mixture was also employed), and in relation to the general theory and practice of seeds mixtures afford some of the most interesting and instructive evidence that has been obtained in connection with the whole series of trials under review.

The state of affairs relative to rough-stalked meadow grass, wild white clover, weeds, and bare ground calls for special comment. It will be noted that on the two series of plots where rough-stalked meadow grass was not included in the mixture (*e.g.*, the " farmers " mixture and clovers only), this grass had none the less contributed 10—11 per cent. to the sward by the second harvest year. On the plots where it had been sown the contribution was, however, over 24 per cent.; moreover, this increase had not been affected by competition, it was practically as great on the 7 species " Cockle Park " plots as on the 5 species " simple " mixture plots. These figures show the advantage of sowing this species on just those lands where it is capable of strong voluntary appearance, when the amount of the appearance will be certainly increased. This is a point of view which the evidence of the trials under review suggests should be applied to every species; the theory being " Do everything possible to augment the contribution of valuable species suitable to the conditions, for there will not be many species so suitable." * It will be noted in each case that high contributions of rough-stalked meadow grass are associated with low or relatively low contributions of weeds and of bare ground. Wild white clover was also strongly endemic to the field, as is shown by a contribution of 11 per cent. to the " red clover only " plots. The difference between the wild white clover contribution on the " red clover only " plots and the " farmers " mixture plots—11 per cent. compared to 4 per cent. (on neither of which had the seed been sown) is important. On the former plots the hay crops were negligible and the competition of shading plants very slight—on the latter plots the shading and competition was considerable, and thus the entry and spread of the local volunteering strain had been greatly hampered and retarded.

This is a state of affairs relative to wild white clover that has been repeatedly noted in connection with the seeds mixture investigations with which one or both of the authors have been concerned over a large number of years.

Equally important is the parallel result that when 1 lb. of wild white was included in the mixture the contribution of white clover was greater on the " simple " mixture plots than on the " Cockle Park " plots. These results show

* Under conditions of extreme infertility it is probably quite legitimate to push the theory to its logical conclusion and to regard such species as the red fescues, bent grasses, and Yorkshire fog as valuable. (See Stapledon (17)).

TABLE XXXIV.—*To compare the botanical composition of the swards in the second harvest year (on the basis of ground analyses) for five types of seeds mixtures and for plots sown with red clover only. Results from lowland centres only; average of very similar data obtained at Nantsiriol and on the Cwm Field of the Station—the "farmers" mixture at Nantsiriol only.* 1927.

Mixtures.	Percentage frequency of the several species.									
	Italian rye-grass.	Perennial rye-grass.	Cocksfoot.	Timothy.	Meadow fescue.	Rough-stalked meadow grass.	Red clover.*	White clover.	Weeds.	Bare ground†
(1) Modified "Cockle Park" 7 species including red clover, wild white clover, and rough-stalked meadow grass ..	2.4	23.7	9.8	2.2	..	24.8	2.7	20.7	13.8	10.2
(10) "Farmers" mixture 5 species. Wild white clover or rough-stalked meadow grass not included	1.0	22.0	15.0	24.0	..	10.0	5.0	4.0	19.0	26.0
(2)—(4) Italian rye-grass 4 lb. with either perennial rye-grass, meadow fescue, cocksfoot or timothy, and with red clover, rough-stalked meadow grass, and wild white clover ..	3.4	47.5	16.9	13.0	17.0	28.1	4.4	31.3	9.2	14.3
(5)—(9) Italian rye-grass 12 lb. and as (2)—(4) above	4.2	45.0	15.8	9.7	9.0	25.5	2.2	34.5	12.5	9.4
Red clover only	0.7‡	1.7‡	0.3‡	3.0‡	..	11.3	3.3	11.0	68.7	8.0

* Average of all nationalities and strains.
† Bare ground estimated separately and not included with the total of the grass and clover species.
‡ Swept in by harrows from adjoining plots at the time of sowing.

the marked benefit of including wild white clover, in respectable amount (in this case 1 lb. per acre) on land where the indigenous local strain is capable of good volunteer appearance—a benefit which shows itself not only in the clover contribution to the sward but in the reduced weed content, and in a lessening of the amount of bare ground. The high weed content and the fact that more than a quarter of the ground was still bare in the second harvest year on the " farmers " plots, on which neither rough-stalked meadow grass nor wild white clover had been sown, is a striking commentary on the importance of including these species in mixtures. They should be so included wherever the conditions for establishment are favourable, and perhaps particularly when they are known to be species strongly indigenous to the field about to be sown out.

The results for the other species do not call for detailed comment. It will be noted, however, that meadow fescue (in a simple mixture) has established itself altogether better under 4 lb. of Italian rye-grass than under 12 lb., thus showing how very sensitive this grass is to competition.

Timothy has behaved in a similar manner, although to a less marked extent. The good timothy contribution in the " farmers " mixture is interesting, having regard to the fact that the seed rate was as high as 8 lb. per acre, and this suggests that the current rate of 4 lb., so frequently employed in 7—10 species mixtures, is seldom high enough. It is also worthy of note that the perennial rye-grass contribution has been higher on the " simple " mixture plots than on the " Cockle Park " or " farmers " plots.

The hay was sampled and analysed at all centres and the results of these separations are confirmatory of the ground analyses just discussed. Certain figures from the second harvest year are, however, of additional interest and are set out in the statement hereunder :—

Selected species.	Percentage contribution of species to the hay in the second harvest year 1927.		
	Simple mixtures with 4 lb. Italian rye-grass.	Simple mixtures with 12 lb. Italian rye-grass.	Modified " Cockle Park " mixture.
Perennial rye-grass	35.1	40.2	28.4
Cocksfoot	14.2	13.9	11.9
Rough-stalked meadow grass	21.6	20.5	16.5
Wild white clover	12.1	8.8	6.4
Broad red clover	1.0	1.0	1.3
Montgomery red clover	13.2	11.6	10.0
Wild red clover	18.5	19.3	21.5

Perennial rye-grass, as in previous trials discussed, contributed more abundantly to the second harvest year hay yields than did cocksfoot. The high contribution of rough-stalked meadow grass is noteworthy and is confirmatory of other results, and shows that when this grass is sown in good amount, and particularly when fields are " put up " late, this species has to be ranked with the important hay species. The contribution of wild white clover to the hay crop has been by no means negligible, and under conditions of minimum competition (4 lb. Italian rye-grass in simple mixture) has been appreciable. The

position taken by wild red clover with actually a higher contribution to the hay crop than that of Montgomery clover is in confirmation of the results from the nationality trial dealt with in the previous section, and constitutes further evidence in support of the apparent value of the best of these strains, perhaps particularly for low fertility conditions.

TABLE XXXV.—*To show the effect of Italian rye-grass when sown respectively at 4 lb. and 12 lb. per acre on the other species included in simple five species mixtures. The results are given in terms of the yields of the several species (in the hay) in lb. dry weight per acre, and are for the second harvest year. Typical upland and lowland centres are compared.* 1927.

Species.	Upland centre.		Lowland centre.	
	Italian rye-grass 4 lb.	Italian rye-grass 12 lb.	Italian rye-grass 4 lb.	Italian rye-grass 12 lb.
Perennial rye-grass	531	568	1030	1245
Cocksfoot	142	123	1200	1282
Timothy	288	151	1230	818
Meadow fescue	139	37	523	347
Rough-stalked meadow grass	120	86	1847	1870
Red clover*	128	98	330	242
White clover	145	82	229	210

* Average of all strains.

The Influence of One Species on Another: The Effect of Italian Rye-Grass on the other Species.

Data are available for comparing the residual effect of Italian rye-grass into the second harvest year at a typical upland centre of low fertility and at a typical lowland centre of high fertility. In considering the results, however, it must be realized that the lowland centre was grazed unusually hard during the spring of both the first and second harvest years, and consequently on this account the competitive effect of both the rye-grasses during the subsequent hay producing periods was greatly reduced. The chief results are set out in Table XXXV. The actual weights per acre contributed by each species to the hay* give a more accurate picture of the competitive influences than do percentages; moreover, percentages cannot be conveniently tabulated, since the data represent results from a number of different mixtures. Reference to the nature of the mixtures employed will remind the reader that perennial rye-grass, cocksfoot, timothy, and meadow fescue were never included together in any one of the simple mixtures here under consideration, but that only one of these species was represented per mixture.

Reference to the table shows that at the high elevation centre (of low fertility but not grazed as exaggeratedly hard in the spring as the lowland centre), all the species with the single exception of perennial rye-grass gave very much lower yields when competing with an initial sowing of 12 lb. Italian rye-grass

* The hay was sampled by taking carefully spaced yard quadrats off the plots; the weights are therefore only approximate and not based on aggregate yields from the produce of the plots weighed *in toto*.

than when set against only 4 lb. This was most marked in the case of meadow fescue, the yield having been reduced to about a quarter of what it was under the lesser seeding of Italian rye-grass. The timothy was reduced to nearly half and the cocksfoot (even in the second harvest year now under consideration) appreciably reduced. A very marked diminution also showed itself in the case of rough-stalked meadow grass, red clover, and white clover.

At the lowland centre (of high fertility but heavily grazed) by the second harvest year perennial rye-grass was yielding decidedly more heavily (proportionately more so than at the high elevation centre) under 12 lb. of Italian rye-grass than under 4 lb., and the same has been true of cocksfoot (in contradistinction to its behaviour at the high elevation). Timothy and meadow fescue again show marked reductions, thus once more proving the sensitiveness of these species to competition. Rough-stalked meadow grass (which has yielded very heavily) shows no reduction, and wild white clover only a negligible reduction. The effect of Italian rye-grass at the two centres can be strikingly compared by estimating the reduction due to the larger sowing on cocksfoot, timothy, meadow fescue, rough-stalked meadow grass, red clover, and white clover considered as one unit. If the yield of these species were expressed as 100 under the 4 lb. Italian rye-grass at each centre, their yield at the high elevation under 12 lb. Italian rye-grass would be 60, and at the low elevation under a similar sowing of Italian rye-grass 91.

These results seem to indicate that under conditions of infertility, the relatively high fertility demanders like cocksfoot, timothy, meadow fescue, and rough-stalked meadow grass suffer more from competition with Italian rye-grass than on more fertile soils—or rather that they will so suffer unless the spring grazing is excessively hard. The evidence from all the centres rather suggests, however, that "grazing hard enough" to eliminate entirely the effects of competition would have to be so hard as to have independently ill effects even on the slower growing species.

On more fertile soils it is feasible to graze hard enough in the spring to reduce considerably the competitive effects of Italian rye-grass without doing irreparable harm to the more permanent species, which are consequently able

TABLE XXXVI.—*To show the influence of perennial rye-grass, cocksfoot, timothy, and meadow fescue respectively on Italian rye-grass when Italian rye-grass was sown with one of these species in conjunction with red clover, white clover, and rough-stalked meadow grass. The figures are given as the percentage contribution of Italian rye-grass to the hay in the first harvest year, based on the average figures from all centres.* 1926.

Species competing with Italian rye-grass.	Per cent. contribution of Italian rye-grass to the hay.	
	Italian rye-grass at 4 lb. per acre.	Italian rye-grass at 12 lb. per acre.
Perennial rye-grass	14.1	26.3
Cocksfoot	28.5	48.3
Timothy	30.9	45.4
Meadow fescue	31.6	45.3

to make substantial headway in the second harvest year; but even so the species most sensitive to competition—meadow fescue and timothy—will still have been appreciably affected by competition in direct proportion to the seed rate of Italian rye-grass.*

The Effect of the Larger Species on Italian Rye-grass.

Competitive influences must of course be reciprocal to some extent, and consequently, although Italian rye-grass is the major aggressor in seeds mixtures, the development of this grass must be influenced by the growth of the other species with which it is sown. The results given in Table XXXVI are interesting in this connection.

The figures in the table show that Italian rye-grass has in all cases contributed more abundantly to the hay crop in the first harvest year when included at 12 lb. per acre than when included at 4 lb. per acre. Perennial rye-grass, which is not hampered by Italian rye-grass to nearly the same extent as are cocksfoot, timothy, and meadow fescue, has reduced the contribution of the aggressor species to a far greater extent than have the other three species. Again, cocksfoot which is less sensitive to Italian rye-grass than meadow fescue or timothy has hampered the aggressor species more than have the latter grasses, although the difference in the amount of effect produced by cocksfoot, timothy, and meadow fescue is not as great as might have been expected.

The Effect of the Larger Species on the Smaller Species.

By an appropriate grouping of the data it is possible to examine the influence of perennial rye-grass, cocksfoot, timothy, and meadow fescue respectively on the other ingredients in the simple five species mixture. The results are given in Table XXXVII. The figures are the average for the mixtures with 4 lb. and 12 lb. of Italian rye-grass and are the average of all the centres from which data are available; they represent yields of the species in lb. dry weight in the hay of the second harvest year.

TABLE XXXVII.—*To show the effect respectively of perennial rye-grass, cocksfoot, timothy, and meadow fescue on the yield in the second harvest year of Italian rye-grass, rough-stalked meadow grass, red clover (average of all strains), white clover, and weeds, in lb. per acre dry weight of the several contributing species.* 1927.

Species for which the yields are given.	When the mixture also included one of these four species:			
	Perennial rye-grass.	Cocksfoot.	Timothy.	Meadow fescue.
Italian rye-grass	80	150	197	250
Rough-stalked meadow grass	757	1257	926	1042
Red clover	98	117	143	115
White clover	150	75	70	92

* In the case of the results immediately under discussion the spring grazing was not only hard but continuous. The correct procedure is, of course, well regulated intermittent grazing.

The figures incidentally demonstrate that the influence of the other larger species on Italian rye-grass as shown to exist in the first harvest year has become rather more exaggerated in the second harvest year, when of course Italian rye-grass in any event will have largely dropped out of the running.

Thus Italian rye-grass exhibits a progressive gain in yield from a minimum with perennial rye-grass, increasing with cocksfoot, increasing again with timothy, and reaching a maximum with meadow fescue. Perennial rye-grass is shown by the figures in the table to rank second only to Italian rye-grass as an aggressor plant, since it has retarded the development of the smaller species (rough-stalked meadow grass and white clover) more than has cocksfoot or timothy or meadow fescue. White clover, however, has been more plentiful with perennial rye-grass than with the other grasses: this would have been largely due to the greater smothering effect of this grass on the red clovers, which in their turn would have exercised less influence on the white clover. As in previous trials, the red clovers have shown to the best relative advantage when associated with timothy.

Comparisons between the Upland and Lowland Centres.

Although the yield data have only been based on quadrat sampling and not on the weights of the total produce of the plots, it is none the less instructive to draw certain comparisons between the typical upland and the typical lowland centre. The upland centre represented an exposed field of decidedly low fertility, and the lowland centre a field of high fertility. In making the comparisons which follow it must be remembered, strikingly in favour of the lowland centre as they are, that this centre was yet handicapped relative to the upland by the excessive spring grazing to which it was subjected. Furthermore, the hay on the lowland centre was cut (and sampled) in the middle of June, while that at the upland centre was not cut (and sampled) till the middle of July.

Aggregate Yields.

The yield data for the three chief types of mixtures are given in Table XXXVIII.

TABLE XXXVIII.—*To show for the second harvest year* (1) *the gross yields in lb. per acre of the hay from the three types of mixture at the upland and lowland centres; and* (2) *the yield of weeds at each centre.* 1927.

Mixtures.	Upland centre.		Lowland centre.	
	Gross yield.	Yield of weeds.	Gross yield.	Yield of weeds.
4 lb. Italian rye-grass with 4 other species	1230	506	4060	407
12 lb. Italian rye-grass with 4 other species	1236	693	4400	504
Adjusted "Cockle Park" 7 species ..	2250	486	4930	197
Average for the 3 mixtures	1572	562	4463	369
Relative with lowland centre 100 ..	35	152	100	100

At both the upland and lowland centres the adjusted "Cockle Park" mixture has considerably outyielded the average of the simpler mixtures. This will have been chiefly due to the fact that this mixture afforded the other species less competition with Italian rye-grass than did the simpler mixtures—of the latter the with-meadow fescue plots in all cases giving low yields.

The average figures show that the upland centre yielded only a little over one-third of the hay crop of the lowland, and this despite the fact that the actual yield of weeds at the upland centre was higher than at the lowland to the extent of half as much again—thus the yield of sown species was very much higher at the lowland centre, and this notwithstanding the very heavy early spring grazing at that centre. The chief unsown species (classed as weeds) rapidly re-gaining the sward at the upland centre were Yorkshire fog, bent grasses, sweet vernal grass, and yellow suckling clover.

The Relationship between the Species.

The different species behaved in an interesting manner at the two centres. The figures available have been averaged for the mixtures with 4 lb. Italian rye-grass and with 12 lb. at each of the centres. When the yield of each species at the lowland centre is placed at 100, the results for the upland centre in the second harvest year are as shown below :—

	Lowland centre.	*Upland centre.*
Perennial rye-grass	100	47
Cocksfoot	100	10
Timothy	100	21
Meadow fescue	100	10
Rough-stalked meadow grass	100	16
Red clover (average of all strains) ..	100	39
White clover	100	51

These relative yields of course represent the contribution of each species under competitive influences (and not as pure plots). The interesting fact is that perennial rye-grass, red clover, and white clover are the three species which have dropped least in yield at the upland centre compared with the lowland—and it is perennial rye-grass and red clover upon which the average hill farmer chiefly relies in his seeds mixtures. Although perennial rye-grass is undoubtedly a high fertility demander, it yet maintains its position well for two harvest years under these low fertility conditions, a result, as already suggested, no doubt largely due to its powers of establishment. Cocksfoot (ordinary commercial) shows itself to be a decidedly high fertility demander, being more exacting than timothy in this respect, and the same is true of meadow fescue and, although to a slightly less extent, of rough-stalked meadow grass. The position taken by both red and white clover is significant—the late flowering red clover would be as high as that of wild white clover (the figure given for red clover is the average of the broad reds and the late flowering reds; the figure for Montgomery red clover alone would be 52). The results suggest that it is of prime importance to the hill farmer to establish a good stand of a correct strain of late flowering red clover and of wild white clover, and also a satisfactory stand of a good strain of perennial rye-grass.*

* It will be remembered that results previously discussed have shown that good strains of indigenous cocksfoot do remarkably well at high elevations and under conditions of low fertility.

The importance of establishing a good clover stand is implied by another set of considerations. If the yield of grasses (aggregate of all sown grass species) when sown with different red clovers is compared for the upland and lowland centres in the second harvest year we obtain results as under :—

	Weight of sown grasses in lb. dry weight per acre.	
	Upland centre.	*Lowland centre.*
When sown with broad red clover ..	353	3443
,, ,, ,, Montgomery red clover	538	3180
,, ,, ,, wild red clover ..	726	3470

At the upland centre the yield of grasses has been directly proportional to the yield and degree of success of the red clover in carrying into the second harvest year. At the lowland centre on the other hand the highest yield of grasses has been on those plots which in the second harvest year were giving the lower clover yields (*i.e.*, on the broad red and wild red clover plots). The reasonable deduction to draw from these facts is that at the lower elevations the grasses were somewhat hampered by the high yielding Montgomery clover and less hampered by the lower yielding clovers. At the higher elevation, soil fertility and not competition was the chief limiting factor to development. Thus even on the wild red (which did so well at the high elevation) and Montgomery plots the growth of the clovers was not sufficient to hamper the grasses, but the effect of the better clover "root" on the wild and Montgomery plots than on the broad red plots was presumably to add to soil fertility, and thus to engender a more vigorous growth on the part of the grasses.

The influence of the various red clovers on the development of wild white clover at the two centres is also of interest. The results cannot, however, be regarded as absolute, because the red clovers were of course included in mixtures, but the cross arrangement of the plots has permitted of averaging a large amount of data and consequently the figures given hereunder are highly significant :—

	Weight of wild white clover in hay in lb. dry weight per acre in the second harvest year.	
	Upland centre.	*Lowland centre.*
When broad red clover was included in the mixture	172	40
When Montgomery red clover was included in the mixture	81	78
When wild red clover was included in the mixture	101	527

The behaviour of wild white clover at the two centres is in almost exactly the opposite direction, but can be explained in a general way in terms of the delaying effect exercised by the red clover during the first harvest year previously referred to. At the upland centre the broad red clover even in the first harvest year gave a very poor yield, being far short of that of the Montgomery or wild red, and thus we see a very much greater development of wild white clover in the second harvest year on the broad red than on the other plots. At the lowland centre the broad red yielded more nearly on a par with the Montgomery, and it was at this centre that the wild red gave much the lowest red clover yield in the first harvest year, with the consequence that by the second harvest year wild white clover showed to very much the best advantage when associated with wild red clover.

SUMMARY AND GENERAL CONCLUSIONS.

(1) This article has dealt with the results obtained from twelve distinct trials set out on 34 different fields. Several of the trials were conducted at a number of different centres. In some cases the data have been carried as far as the fifth harvest year, most frequently the results have been carried to the third harvest year, in one trial only first harvest year data have been available, while in a few important experiments second harvest year results have alone been collected.

(2) The large number of trials and of fields involved has made it possible to study the effects of soil condition and of management in considerable detail, and it is the results with reference to these points that have proved of the greatest interest.

(3) Seeds mixtures sown on fields not well cleaned and which are congenial to the almost immediate re-entry of Yorkshire fog and bent give rise to swards which are subject to very rapid deterioration. Under these circumstances the hay yields fall off rapidly from year to year, while in extreme cases the contribution of sown species to the sward by the fourth harvest year may be less than 10 per cent.

(4) The trend of deterioration can be largely retarded by heavy intermittent grazing, and, provided the grazing is adequate and well regulated, deterioration is not so rapid under grazing conditions as when hay crops are taken in the earlier harvest years.

(5) Under poor conditions for soil establishment followed by smothering due to rapid bent and Yorkshire fog domination, deterioration is rendered the more rapid as the result of delayed germination and delayed growth of the sown species, a state of affairs which is further accentuated if insufficient treading by the grazing animal is permitted consequent upon under-stocking.

(6) Heavy sowings of rough-stalked meadow grass (2—6 lb. per acre), wild white clover (1—3 lb.), crested dogstail (2—6 lb.), and Chewing's fescue are competent to stay deterioration, and make for the rapid development of a close bottom sward, provided the conditions are rendered favourable to the immediate establishment and subsequent development of these species.

The best results will be obtained when the land is comparatively clean and when the sward is at no time subjected to smothering conditions: that is to say, when these species are not sown under a cereal crop, are not permitted to grow in competition with luxuriant rye-grasses, late flowering red clover and other aggressive species, and are not allowed to be obstructed by dense growth of bent and Yorkshire fog. These conditions are to be achieved when such mixtures are sown without a nurse crop, or under rape, and are grazed on an intermittent basis as soon as possible. If hay is taken, the crop should be " put up " late and cut early, a heavy hay crop on no account being allowed to develop.

Simple mixtures pivoted on large sowings of rough-stalked meadow grass and wild white clover managed on the basis indicated have shown less than 5 per cent. weeds in the second harvest year compared to ill-managed complicated mixtures, which have shown over 20 per cent. By a fifth harvest year, weeds on swards developed from the simple mixtures in most cases have not exceeded 20 per cent., compared to weed contributions of over 90 per cent. from more ordinary mixtures under poor management.

The evidence conclusively suggests that large sowings (2 lb. and upwards) of wild white clover and rough-stalked meadow grass will usually be justified when supported by proper preparation of the land and (or) by management designed to favour these species to the maximum from the very outset.

(7) The evidence suggests that it is just on those soils to which wild white clover and rough-stalked meadow grass are strongly indigenous that these species in large amount can be included in the mixtures to the very best advantage. Examples have been quoted where under such conditions excellent swards having all the characteristics of fine old permanent pastures have been developed within a few months of sowing : the contrast between plots on which these species were included and those from which they were excluded constituting perhaps the most informing results obtained in connection with the extensive trials under review.

It is probable that the most far reaching lesson so far learned from the seeds mixture investigations in progress at the Station is the fact that rough-stalked meadow grass is to be regarded as one of the most important species for inclusion in seeds mixtures in regions of high rainfall. The minimum effective seed rate is undoubtedly as high as 2 lb. per acre.

(8) Indigenous strains of perennial rye-grass, cocksfoot or timothy (and in some cases of all three species) compared with the ordinary commercial strains were included in mixtures associated with five of the trials under discussion. In three of these trials the results were overwhelmingly in favour of the indigenous strains, in the fourth the advantage was decidedly in their favour, and in the fifth on the average of the three harvest years (including hay and aftermath) the aggregate yields were slightly in favour of the indigenous.

The good showing of the indigenous strains was most noteworthy in the later harvest years, and is the more remarkable having regard to the fact that in all cases the lots represented only preliminary " mass " selections and not " finished " products, the result of completed breeding work.

The indigenous cocksfoot showed marked promise as a grazing grass, perhaps more particularly for conditions of poor fertility, and the indigenous timothy suggests the possibility of building up a really good pasture strain of this essentially hay species. The results given by indigenous perennial rye-grass (cleaned from wild white clover) in a large number of trials may be taken to have definitely established the immense value of this commercial commodity.

(9) The results obtained with different nationalities and regional strains of red clover have in the main been in confirmation of Williams's earlier trials ; Montgomery extra-late red clover has fully justified its reputation ; the Swedish late clover, more particularly at the higher elevations, has not, however, done as well as was expected. The most interesting fact in connection with the red clovers has been the signal success at the higher elevations of low fertility of the excellent strain of wild red clover that was employed : the implication now being that the best strains of this variety may prove to be of real economic importance for conditions of low fertility.

(10) The behaviour of typical mixtures at a lowland centre of high fertility and at an upland centre of poor fertility gave interesting results. The yields at the upland centre were only a little over a third of those at the lowland. The yield of unsown species (chiefly weeds) was, however, nearly half as much again at the upland as at the lowland centre. Relatively, Montgomery red

clover, wild red clover, wild white clover, and perennial rye-grass maintained their yielding ability at the upland centre better than did other species—timothy showed to better advantage than cocksfoot or meadow fescue.*

Under conditions of poor fertility at the upland centre, the evidence suggests that the better clover "root" developed by Montgomery red clover and wild white clover than by broad red clover (the broad reds show to very poor advantage at the upland centres) acted favourably on the development of the grasses, presumably as a consequence of the clovers' beneficial influence on soil fertility: the growth even of the most successful clovers not here being sufficient to hamper the grasses materially.

(11) Provided good establishment is achieved and the hay is not cut too early,† a genuine strain of late flowering red clover must be ranked as perhaps the heaviest potential contributor to the hay crop in a mixture during the first and second harvest years. Under these circumstances it follows that the yield of hay attained to will be more dependent on the development of late flowering red clover as such than upon the yield of whatever species may be sown with this clover. If the grasses yield to excess, the clover will be hampered, and the aggregate yield over the two years is likely to be less than if the clover is allowed full play. Timothy and late flowering red clover give very heavy hay yields over two harvest years; this is not because of a high timothy contribution but simply because this grass hampers the clover less than do any of the other larger species. More than one "hay" grass (*e.g.*, perennial rye-grass and cocksfoot, or cocksfoot and timothy) hampers clover development more than does one "hay" grass, consequently late flowering red clover with say, either timothy or perennial rye-grass or cocksfoot will usually give heavier aggregate hay crops from the first and second harvest years taken together than will this clover in a mixture with two or all three of these "hay" grasses.

In general, it may in fact be said that one-grass-one-clover (late flowering red clover) mixtures will give as heavy (or heavier) hay crops taking the first two harvest years together than will two-to-three grasses one-clover (late flowering red clover) mixtures, provided always the "hay" grass is one competent to yield well in both harvest years, that is to say, not Italian rye-grass or an essentially pasture grass like crested dogstail. It must be remembered further that the dominance of the late flowering red clover is always favoured by late "putting up" to hay when the earlier grasses are always more hampered than the later clover by prolonged spring grazing. Late flowering red clover alone will not, however, yield as heavily as an association of the clover with one appropriate grass species, nor is the clover alone competent to keep the land reasonably free from weeds even during the first harvest year.

If the hay is cut too late in the first harvest year the development of the late flowering red clover may be so great and so advanced that its persistency into the second year will be impaired, with consequent great reduction in the crop of the second year. On the other hand, if the hay crop is cut early in both years the red clover will of course be unable to make its full contribution, and under these circumstances a two-to-three-grasses-one-clover mixture is liable to yield more heavily than a one-grass-one-clover mixture.

* The above remarks refer only to the ordinary commercial strains.

† The precise contribution of late flowering red clover to the hay crop is peculiarly sensitive to the date of cutting. Cases have come under observation where the hay has been cut early in June, in which the late flowering red clover contribution to the hay was no more than 5 per cent. In 1927, owing to the weather breaking on June 16th, much hay was not cut till after the middle of July; some of these hay crops have contained as much as 90 per cent. of late flowering red clover.

(12) In the majority of the trials under review perennial rye-grass has yielded more heavily in competitive mixtures than cocksfoot in the first and second harvest years, although cocksfoot has sometimes yielded the more heavily in the second year.

Broadly speaking, however, cocksfoot or meadow fescue (on soils that suit them) included in a mixture instead of perennial rye-grass (and thus unhampered by the rye-grass) has occasioned as high aggregate hay yields over the two years as has the rye-grass ; and in some cases appreciably higher yields.

(13) When aftermath is considered as well merely as hay, cocksfoot assumes added importance, being vastly superior to perennial rye-grass or timothy in this respect. The addition of cocksfoot to mixtures (or the inclusion of cocksfoot as the only " hay " grass) is consequently always justified on the score of the production of after-grass alone.

(14) Italian rye-grass added to the mixture, and especially if in large amount and not heavily grazed in the spring, is usually responsible for a reduction in hay yield during the first and second harvest years ; but as well as providing for early spring grazing, it will increase the after-grass.

(15) By the third and subsequent harvest years, late flowering red clover will have ceased to contribute appreciably to the hay yield, and it is then that reliance has to be placed on the more persistent of the bulky grasses. It is in this connection that the indigenous strains (considered now as hay as much as pasture plants) have proved themselves so immensely valuable.

(16) Rough-stalked meadow grass is capable of appreciable contribution to the hay even in the first harvest year (particularly when the fields are " put up " late) and of very considerable contribution in the second year. This grass and even crested dogstail in later harvest years often contribute decidedly more to the hay than do the surviving plants (commercial) of such essentially hay grasses as cocksfoot, timothy, or even perennial rye-grass. Speaking in terms of the commercial strains, perennial rye-grass has most usually persisted into the fourth and fifth harvest years better than any of the other larger species, with the exception of tall fescue. This latter grass, although a heavy yielder and capable of good early spring growth and abundant aftermath production, has not, however, proved to be palatable or relished by stock under the conditions of our trials.

(17) These experiments have confirmed absolutely the earlier trials as showing that except on fields of unusually high fertility or perhaps under continuous heavy manuring the only species (when represented by the ordinary seed of commerce) which can be regarded as usefully persistent subsequent to the fourth harvest year are rough-stalked meadow grass, crested dogstail, and wild white clover. The indications now are that to this list will probably have to be added good strains of wild red clover and improved indigenous strains of perennial rye-grass, cocksfoot, and perhaps timothy also, as well as red fescue and tall fescue, although on the score of low palatability the last two species are of problematical value, except perhaps under conditions of the lowest possible fertility.

(18) The colonization by unsown species has been studied in some detail ; the whole trend of that colonization will be determined by the earliness of the re-entry of bent grasses and Yorkshire fog in particular and by the degree of

control which is exercised on these species if they make an immediate and abundant appearance. On many of the fields under review rough-stalked meadow grass, wild white clover, and yellow suckling clover have frequently been early and abundant volunteers—other grasses and clover species to volunteer have been sweet vernal grass, *Holcus mollis*, *Lotus corniculatus*, crested dogstail and *Festuca rubra*. By the fourth harvest year on one of the fields under study as many as 24 species had made a spontaneous appearance, while four additional species were introduced as impurities in the seeds sown.

(19) The detailed evidence relative to competition and the effect of one species on another will be most usefully summarized in conjunction with the data to be brought under review in the next article, which deals with a critical study of the various factors involved.

THE FACTOR OF COMPETITION BETWEEN ONE SPECIES AND ANOTHER IN SEEDS MIXTURES.

BY

WILLIAM DAVIES, M.Sc.

B. 137 II : BOX EXPERIMENT TO TEST THE EFFECT OF COMPETITION UPON ESTABLISHMENT AND YIELD IN THREE GRASSES : GARDENS : SOWN 1924.

This experiment was designed to test the soil establishment of the rye-grasses and of cocksfoot when sown under control conditions in the greenhouse at the Gardens and also to test the effects of seed rate, together with the influence of rye-grass upon the yield and flowering capacity of cocksfoot.

MATERIAL AND METHODS.

Sixty boxes, each measuring about 20 inches by 14 inches by 7 inches deep, were filled to a depth of 5 inches with dry soil. Sterilised soil was used so as to ensure freedom from weed and other extraneous seeds. Spaced drills of cocksfoot were sown alternately with drills of either perennial or Italian rye-grass : the seeds were spaced at $\frac{1}{2}$ inch, 1 inch, 2 inches and 3 inches apart in the drills ; the drills themselves being set at similar distances. Each seed was therefore allowed either $\frac{1}{4}$ square inch, 1 square inch, 4 square inches or 9 square inches. Control boxes (= pure plots) were sown with cocksfoot, perennial rye-grass, and Italian rye-grass respectively, each at the stated spacings. Further details of seeding are set out in Table I.

TABLE I.—*Showing the spacing and seeding. Box experiment in the Gardens : sown May 9th, 1924.* *B. 137. II.*

No. of mixture.	Species.	Distance between drills and between each seed in the drill.			
		Method A.	Method B.	Method C.	Method D.
1	Perennial rye-grass ..	½ inch.	1 inch.	2 inches.	3 inches.
2	Perennial rye-grass and cocksfoot.. ..	,,	,,	,,	,,
3	Cocksfoot	,,	,,	,,	,,
4	Italian rye-grass	,,	,,	,,	,,
5	Italian rye-grass and cocksfoot.. ..	,,	,,	,,	,,

The " seeds " were placed in position with the aid of ordinary dissecting forceps, and immediately after sowing dry soil was carefully laid on them to a depth of $\frac{1}{2}$ inch. This was pressed hard into position, so as to make a firm seed bed. The sowing operations were of necessity spread over a number of days, and during this period the boxes were kept dry in the greenhouse : watering commenced on May 9th, 1924. Each plot (= box) was replicated three times.

The boxes were taken into the open from the greenhouse on June 1st, 1924 (23 days after sowing, when the seedlings had made strong growth), and were sunk in soil to a depth of about 6 inches. The boxes were left in their new position until after the completion of the experiment in the first harvest year, 1925.

Counts of seedlings were made at three dates in the seeding year and a final analysis was carried out in June, 1925—the percentage soil establishment was calculated for each count made.

The produce was cut twice during the seeding year and again for hay in the first harvest year ; botanical analyses were made on each sample. The number of cocksfoot panicles in the hay, together with their average heights, was ascertained and a comparative statement made for each treatment.

Discussion of Results.

(1) *Percentage establishment of viable seed. Commentary on Tables II and III.*

The average percentage establishment for each of the three grasses, irrespective of treatment, is summarized in Table II.

TABLE II.—*Showing the percentage establishment of viable seed for rye-grass and cocksfoot. Box experiment in the Gardens. Sown May 9th, 1924.*
B. 137. II.

Date of count.	Number of days after sowing.	Italian rye-grass.	Perennial rye-grass.	Cocksfoot.	Average.
20/5/24	11	86.4	84.9	77.5	82.9
31/5/24	22	88.2	87.8	79.0	85.0
10/7/24	62	86.3	85.3	75.8	82.8
10/6/25	397	67.5	78.4	64.7	70.2
Average establishment in the seeding year	..	87.0	86.0	77.4	..
Average establishment in the field trials (seeding year)*	..	43.6	53.1	35.8	..

* See Welsh Plant Breeding Station Bulletin, Series H. No. 6. May, 1927.

The results indicate that under exceptionally favourable conditions for soil germination these species make altogether better establishments than are normally attained to in the field. The comparative statement given in Table

II comprising also data extracted from results previously published* emphasizes the wide differences between establishment under the favourable environment of the greenhouse and that under average field conditions.

The present data, however, demonstrate that even under the favourable conditions of this trial, soil establishment has in all three species fallen considerably short of laboratory germination, which in the case of the carefully selected seed employed, representing samples of high viability, may be taken as practically 100 per cent. for each species.† As in field trials, the rye-grasses have made better establishments than cocksfoot. There is evidence showing some delay in soil germination for each of the species, as a comparison of results obtained respectively 11 and 22 days after sowing will demonstrate : (see Table II). The later counts (62 days and 397 days after sowing) show a progressive decrease in plant numbers.

It is of interest to note that Italian rye-grass by the first harvest year has decreased in establishment to a greater relative extent than either perennial rye-grass or cocksfoot. Italian rye-grass being of rapid growth in the early stages of development is aggressive, and therefore sets up a keen intra-specific competition which, coupled with its biennial nature, tends to reduce its own numbers by plant suppression.

It has been asserted,‡ and probably correctly asserted, that soil fauna have an important influence in reducing the soil establishment of herbage plants. In the present experiment, data were collected to estimate the effect of slug attack. A number of seedlings were found to have been eaten off to ground level by slugs : plants in the " spear " (= first leaf) stage appeared to be most palatable, and, as would be expected, the seedlings were unable to recover after complete defoliation at this critical growth stage. Three hundred seedlings were examined, but only 5 of these (= 1.7 per cent.) were damaged or killed by this means. The seedlings had, however, been started off in the greenhouse under conditions not suitable to slugs, and in the majority of cases had passed the critical " spear " stage before being placed in the open. The figure of 1.7 per cent. must, therefore, be considered as low in comparison with that which would be expected under conditions more nearly approaching those normally attained to in the field.

Data given in Table III show the effect of close spacing (corresponding to increased seed rates) upon establishment and also the relation of establishment in the first harvest year to that found in the seeding year. Plant counts made 22 days after sowing are placed at 100 for each species as such and the number of plants at 62 and 397 days respectively are given as percentages of those recorded at the earlier date. The results permit of the following conclusions :

(*a*) When the seed rate is increased (reduced spacing) percentage establishment is lowered as the result of competitive interaction between the more closely packed plants. This is in keeping with results obtained from field trials conducted at the Station (see Davies (6)).

(*b*) This result is more apparent in the first harvest year than in the seeding year, as would naturally be expected when the intensity of competition in hay is considered.

* See Davies (5).
† No inert matter was sown and therefore laboratory germination equals real value.
‡ See, for example, Anderson, (1).

TABLE III.—*Showing* (1) *the relation between establishment at three contrasting seed rates* (= 1 *inch*, 2 *inch and* 3 *inch spacings*); (2) *the relation of establishment in the first harvest year to the highest establishment recorded in the seeding year. Sown May 9th,* 1924. *Establishment on May* 31*st,* 1924 (22 *days after sowing*) *placed at* 100 *for each species as such. Garden box experiment.* *B.* 137. *II.*

Species.	Seeding year 10/7/24 (62 days after sowing).			1st harvest year 10/6/25 (397 days after sowing).		
	B.	C.	D.	B.	C.	D.
	Spaced 1 inch (full seeding).	Spaced 2 inches (¼ seeding).	Spaced 3 inches (1/9th seeding).	Spaced 1 inch (full seeding).	Spaced 2 inches (¼ seeding).	Spaced 3 inches (1/9th seeding).
Perennial rye-grass ..	91.6	100.0	100.0	*	83.8	97.8
Italian rye-grass ..	96.0	98.4	99.4	*	64.9	90.0
Cocksfoot	90.0	96.7	97.3	*	71.2	94.8
Average	92.5	98.4	98.9	..	73.3	94.2

* Accurate counts not possible.

(2) *Yields of cocksfoot sown alone and in competition with rye-grass. Comments on Tables IV and V.*

Data representing total yields from cocksfoot obtained at 3 cutting dates are given in Table IV. The first cut was made 8 weeks after sowing, and even at this early stage Italian rye-grass is shown to have depressed the cocksfoot yield; the effect is, however, more evident at the later cuts, and is perhaps most

TABLE IV.—*Showing the total yields of cocksfoot when sown* (1) *alone, and* (2) *with rye-grasses. Air-dried weights in grammes per box. Garden box experiment. Sown* 1924. *B.* 137. *II.*

Date of cutting.	Number of weeks after sowing.	Cocksfoot.		
		Alone.	With perennial rye-grass.	With Italian rye-grass.
7/7/24	8	59.9	33.5	15.8
3/12/24	30	75.8	17.1	4.4
10/6/25	56	334.8	146.8	27.0
Total of 3 cuts	..	470.5	197.4	47.2
Relative yields	..	100	42	10

TABLE V.—*Showing the yield per plant in cocksfoot when sown* (1) *alone, and* (2) *with the rye-grasses. Air-dried weights in milligrammes per plant. Three cutting dates* 1924—1925. *Garden box experiment.* *B.* 137. *II.*

Date of cutting.	No. of weeks after sowing.	Cocksfoot.			"Cocksfoot with rye-grass" when "cocksfoot alone" = 100
		Alone.	With perennial rye-grass.	With Italian rye-grass.	
7/7/24	8	770	820	540	88
3/12/24	30	1,300	880	380	48
10/6/25	56	12,050	11,580	2,230	57
Total of 3 cuts	..	14,120	13,280	3,150	..
Relative yields per plant (= vigour) ..	..	100	95	22	..

pronounced in the hay of the first harvest year. The figures indicate that cocksfoot is influenced to a greater extent by Italian rye-grass than by the less rapidly developing perennial rye-grass.*

Table V shows the effect of competition with rye-grasses upon the vigour of growth of cocksfoot as measured by the average yield per plant. These data are in keeping with those given in Table IV, and again show Italian rye-grass to be more effective than perennial rye-grass in reducing the yield of cocksfoot.

The figures for total yield and for vigour (yield per plant) of cocksfoot when sown alone and when sown in competition with the rye-grasses are given in Tables IV and V respectively: these are of particular interest because they indicate the relative effect of each rye-grass upon cocksfoot during the first 13 months after sowing. Italian rye-grass has reduced the relative gross yields of cocksfoot from 100 to 10, or on the basis of an adjusted seed rate from 100 : 20, whilst the comparable figure for yield per plant is 100 : 22. The figures further indicate that in this experiment few, if any, plants were actually killed as a consequence of competition.

(3) *Effect of the Rye-grasses upon Flowering in Cocksfoot. Comments on Tables V I and V I I.*

The data relating to the number of cocksfoot inflorescences in first year's hay are summarized in Table VI. Reduction in general vigour due to rye-grass competition is accompanied by a reduction also in the number of flowering stems. The average panicle production per plant is given in the table for the three wider spacings only—accurate plant counts being possible only in these instances. These results clearly demonstrate that the number of inflorescences produced per plant have been markedly lowered by inclusion of the rye-grasses—Italian rye-grass again having the most pronounced effect. Had it been found possible to make accurate counts of established plants at the close spacings ($\frac{1}{2}$ inch and 1 inch), the figures for average panicle production per plant would have shown still wider differences.

* See Davies and Thomas, (7), for a discussion of relative growth rates from seed in herbage plants.

TABLE VI.—*Showing* (1) *the extent of panicle production in cocksfoot*: (2) *the influence of rye-grasses in first year's hay upon number of cocksfoot panicles. Garden box experiment. Sown* 1924. *B.* 137. *II.*

Species.	Cocksfoot.		
	Average number of panicles per box ½ inch to 3 inch spacings.	Average number of panicles per plant 2 inch to 3 inch spacings.*	Relative number of panicles per plant.
Cocksfoot alone	194.2	6.96	100
Cocksfoot with perennial rye-grass ..	61.7	5.12	74
Cocksfoot with Italian rye-grass ..	11.6	1.61	23

* It was not possible to make accurate plant counts of the closer spacings.

Table VII gives the average height of the flowering stems in cocksfoot as measured from ground level to the ligule of the flag leaf,* and to the apex of the panicle. The panicles are shortened when cocksfoot is sown thickly: plants spaced at distances of from 3 inches to 1 inch do not show marked differences in the mean heights of their flowering stems. When the spacing is further reduced to ½ inch there is considerable reduction in total height as well as in the length of panicle.

Table VII (*b*) shows that sowings of rye-grass have depressed the vigour of flowering in cocksfoot as measured by the mean length of flowering stem.

TABLE VII.—*Showing the effect of competition upon the mean height of the flowering stems of cocksfoot in the hay. Measurements in cms. First harvest year. Garden box experiment. Sown* 1924. *B.* 137. *II.*

Species and spacing.	Average height		Difference.
	to apex of panicle.	to upper ligule.	
(*a*) Pure cocksfoot—effect of seed rate			
3 inch spacing	101	78	23
2 ,, ,, ...	103	80	23
1 ,, ,, ...	101	78	23
½ ,, ,, ...	93	73	20
(*b*) Effect of the rye-grasses in the mixture.			
Without rye-grass	112	85	27
With perennial rye-grass only ..	102	78	24
With Italian rye-grass only ..	86	68	18

* Flag leaf=upper stem leaf subtending the panicle.

There are well-marked indications to show that the panicles themselves become shorter as the competition becomes more intense—compare, for example, the figures in the right-hand column (Table VII (*b*)).

These data would appear incidentally to suggest that plant competition may have an important bearing upon seed yield under conditions normally adopted relative to seed production.

B. 137 II : Summary to the Experiment.

(1) Italian rye-grass is more aggressive in competition than perennial rye-grass. Both rye-grasses are highly aggressive towards cocksfoot.

(2) If cocksfoot is grown under severe competitive conditions with the rye-grasses its gross yield is reduced, and this is accompanied by a reduction in vigour as measured by (*a*) the mean yield per plant : (*b*) the number and length of flowering stems per plant : and (*c*) the size of the panicle.

(3) There is direct evidence of delayed germination of sown seed extending to at least two months after the date of sowing.

(4) Closer spacing (and therefore heavier seed rates) by virtue of producing keener competition had a depressant effect upon percentage establishment of viable seed in the rye-grasses and in cocksfoot.

E. 55 : SEEDS MIXTURE EXPERIMENT TO TEST THE EFFECT OF VARIOUS " LARGE GRASSES " UPON THE ESTABLISHMENT OF TIMOTHY AND LATE RED CLOVER : LANE FIELD. SOWN 1924.

This experiment was primarily designed to test the effect of a number of grass species upon the soil establishment of timothy when sown in a simple mixture. Twenty-nine seeds mixtures were sown in 93 1/400th acre plots. Details of the seeding are given in Table VIII, reference to which will show that seven species of grasses have been tested in regard to their influence upon timothy. These seven species have each been sown at 4 independent seed rates, the rates always being in the ratio 1 : 2 : 4 : 6 for any one species. The seed rates adopted aimed at establishing an equal number of plants in the case of each " aggressor " species. For example, 5.5 lb. per acre of perennial rye-grass (Plot A1) was calculated to give rise to approximately the same number of plants per unit of area as 6.7 lb. per acre of Italian rye-grass. These calculations were based on establishment data available at that time—more exact soil establishment results have been recently published from the Station.* The sowings of cocksfoot, timothy, tall oat grass, meadow fescue, and tall fescue in mixtures C1, D1, E1, F1, G1, respectively, were designed to produce the same number of plants as that given by 5.5 lb. perennial rye-grass. In the same manner mixtures 2, 3 and 4 were expected to give an equal stand, as measured by numbers, for the several so-called " aggressor " species under test. A basal mixture consisting of timothy and red clover was used throughout as well as for the standard or check mixture. It will further be noted that in group " D " timothy was used as an " aggressor " in the same way as other species—seedings in this case simply involving an increased rate of sowing in timothy itself. Commercial strains of the grasses were used throughout.

* See Stapledon, Davies and Beddows, (21), and Davies, (5).

TABLE VIII.—*Showing details of the seeds mixtures sown—lb. per acre at real value* 100 : 29 *mixtures* × 3 : *sown May 29th,* 1924. *E.* 55 : *Lane Field.*

"Aggressor" grass.	Perennial rye-grass.				Italian rye-grass.				Cocksfoot.				Timothy.				Tall oat grass.				Meadow fescue.				Tall fescue.				Check = standard.
Ref. no. of mixture ..	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	F2	F3	F4	G1	G2	G3	G4	
Perennial rye-grass ..	5.5	11.0	22.0	33.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Italian rye-grass ..	..	..	..	..	6.7	13.3	26.6	39.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Cocksfoot ..	..	..	..	..	..	..	..	..	5.6	11.1	22.2	33.3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Timothy ..	..	..	..	..	..	..	..	..	..	..	..	..	3.2	6.4	12.8	19.2	..	..	..	..	..	..	..	..	..	..	..	..	..
Tall oat grass	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11.3	22.5	45.0	67.5	..	..	..	..	..	..	..	..	..
Meadow fescue	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10.3	20.5	41.0	61.5	..	..	..	..	..
Tall fescue ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9.2	18.3	36.6	54.9	..
Basal mixture.																													
Timothy ..	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Montgomery red clover ..	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

TABLE IX.—*Showing the relative total yield of hay in* 1925 : *comparison of the seven "aggressor" grasses at each of the* 4 *seed rates. Figures based on growth marks* 0—10 *given to the standing hay crop ; totals of* 3 *replications* : *E.* 55 : *Lane Field* : *sown* 1924.

Main "aggressor" constituent	Perennial rye-grass.	Italian rye-grass.	Cocksfoot.	Timothy.	Tall oat grass.	Meadow fescue.	Tall fescue.	Total.	With rate 1 at 100.
Reference number of group.	A.	B.	C.	D.	E.	F.	G.		
Seed rate of "aggressor."									
Rate 1 (basal rate)	20.0	12.0	9.0	12.0	10.0	11.5	12.0	86.5	100
„ 2 (1 × 2)	23.0	16.0	10.0	13.5	12.0	12.5	12.0	99.0	114
„ 3 (1 × 4)	19.5	15.0	12.0	12.5	12.5	12.0	14.5	98.0	113
„ 4 (1 × 6)	17.0	15.5	11.0	12.5	12.5	12.0	13.0	93.5	108
Average	19.9	14.6	10.5	12.6	11.8	12.0	12.9	..	..

The experiment was sown on May 29th, 1924, without a nurse crop : the soil was a clay loam, inclined to be wet. General sowing conditions were good and the seeds went down well. Light grazing of the plots was carried out during the late summer, autumn and winter of 1924-25, the plots being enclosed for hay on February 12th, 1925. No hay yields were taken, the plots being cut for the first year hay in June, 1925, and treated as a commercial crop.

Detailed analysis of the number of established seedlings was made in August of the seeding year, whilst a further count was taken a year later—in August of the first harvest year. Ten readings using the 6 inch by 6 inch mesh were taken on each plot in each of the two years.

Discussion of Results.

(1) *Productivity as Hay in the First Harvest Year.*

The hay was not weighed ; observational marks given on a scale 0—10 were, however, allotted to each plot before mowing in the first harvest year. The results are shown in Table IX, and indicate the comparative yields of the various plots both in respect of the main grass constituent and in regard to the seed rate of the grass which was used. The plots including the rye-grasses, and especially those with perennial rye-grass, gave heavier yields of hay than the plots sown with other grasses. This result is highly significant when the heavy nature of the soil under the experiment is taken into consideration—it indicates how elastic the rye-grasses can be in respect of adapting themselves to a wide range of edaphic conditions. The low relative yield of tall oat grass (group E) is similarly of significance : this species does well on light soil and in relatively dry situations, under which conditions it is one of the highest yielders. The failure of tall oat grass in the present trial has been largely a function of an indifferent "take."

The effect of increasing the seed rate upon gross yield is interesting. The results show that thicker sowings do not necessarily imply higher yields ; indeed, if the seeding is too heavy, excessive competition appears to influence the productivity adversely. This point is reached with a lower seed rate of the two rye-grasses than of other grasses, indicating, therefore, the highly aggressive nature of the rye-grasses.

(2) *Percentage Establishment of Viable Seed.*

(*a*) *Effect of Competition upon Establishment.*

Table X shows the effect of increasing the seed rates upon the establishment of each grass included in the trial. Thicker sowing has resulted in the reduction of percentage establishment, and this appears within the limits of experimental error to hold in all cases, and is in corroboration of observations made by Davies (6).

The data in Table XI demonstrate that the rye-grasses, particularly Italian rye-grass, exert a more adverse influence upon the establishment of timothy than do other species. Tall oat grass and cocksfoot are normally aggressive in relation to timothy, but in view of their poor establishments they have not in this trial had an adverse effect upon the latter. The comparatively non-aggressive nature of the fescues during the seeding year is noteworthy, but there are indications to show that on this heavy land the fescues have been able to suppress timothy in the first harvest year to a greater extent than most species, and to at least as great an extent as perennial rye-grass. The average figures

TABLE X.—*Showing the percentage establishment of viable seed when certain grasses are sown at four contrasting seed rates. (Average figures for seeding and first harvest years) : E. 55 : Lane Field. Sown* 1925.

Species.	Rate 1 (basal rate).	Rate 2 (1 × 2).	Rate 3 (1 × 4).	Rate 4 (1 × 6).	Average.
Perennial rye-grass ..	65.1	50.2	36.4	25.5	44.3
Italian rye-grass ..	44.9	42.9	23.5	26.2	34.4
Cocksfoot	14.6	14.6	10.1	8.2	11.9
Timothy	17.8	14.7	9.5	8.4	12.6
Tall oat grass	13.6	16.6	14.2	10.1	13.6
Meadow fescue	19.6	21.0	14.1	13.3	17.0
Tall fescue	40.4	32.2	30.2	27.0	32.5
Average	30.9	27.5	19.7	17.0	..

in the right-hand column of the table illustrate that increased sowings of the "aggressor" species have made for markedly lower establishments in timothy both in the seeding and first harvest years. A general comparison of the results for the two years will show that the casualties in timothy for the period have been very heavy.

The data relative to tall oat grass and to tall fescue call for further consideration. The former species is indigenous to dry, well drained soils (as exampled by hedgerows and banks) whilst the natural habitats of tall fescue are heavy loams and clay soils. To refer again to Table X, giving data collected—be it noted—from a trial conducted on a clay soil, it will be seen that whereas tall fescue has made good establishment, tall oat grass on the other hand has

TABLE XI.—*Showing the effect of increasing the seed rate of the "aggressor" grass upon the soil establishment of timothy. Seeding year and first harvest year : E. 55. Lane Field.* 1924—1925.

Seed rate of the aggressor species.		With perennial rye-grass.	With Italian rye-grass.	With cocksfoot.	With timothy.	With tall oat grass.	With meadow fescue.	With tall fescue.	Average.	Relative.
Seeding year.	Rate 1	22.0	11.0	22.3	25.1	29.4	17.3	25.0	21.7	100
,,	Rate 2	12.9	9.9	16.9	20.7	18.2	22.5	20.8	17.4	80
,,	Rate 3	13.6	5.3	16.6	13.5	23.7	19.3	23.8	16.5	76
,,	Rate 4	7.2	10.0	13.9	12.7	10.4	21.5	14.4	12.9	59
Average		13.9	9.1	17.4	18.0	20.4	20.2	21.0	..	..
1st harvest year.	Rate 1	8.6	4.0	11.0	10.4	11.6	9.6	8.7	9.1	100
,,	Rate 2	4.5	3.1	8.5	8.6	11.6	5.4	6.1	6.8	75
,,	Rate 3	4.6	2.7	8.8	5.5	6.8	4.6	4.1	5.3	58
,,	Rate 4	4.8	1.5	7.6	4.0	8.1	3.8	4.1	4.8	53
Average		5.6	2.8	9.0	7.1	9.5	5.9	5.8	..	..
Average for 2 years		9.8	6.0	13.2	12.6	15.0	13.1	13.4	..	..

given abnormally poor results in comparison with average soil establishment in Wales (see Davies (5)). Establishment, therefore, appears to bear some relation to the " natural " habitat of the species concerned. The average figures given in Table X further demonstrate that the rye-grasses are capable of fairly good establishment even under conditions not eminently suited to their maximum development.

(*b*) *Comparison of Establishment in the Seeding and First Harvest Years.*

Comparative data have been summarized in Table XII relative to establishment in the seeding and first harvest years. In many species there appears to be a fall in numbers as from the first summer (seeding year) to the first harvest year, but this is far more pronounced in some species than in others. In the present trial the figures for timothy, tall oat grass, cocksfoot, and Italian rye-grass have shown the greatest drop, whilst perennial rye-grass and tall fescue have retained approximately their original establishments. Meadow fescue and Montgomery red clover on the other hand have shown an increase in numbers. This result may at first appear surprising, but it is, however, in accord with the data recorded by Stapledon, Davies and Beddows (21).

TABLE XII.—*Showing the average percentage establishment of viable seed : seeding year and first harvest year data compared :* 1924—25 : *(average of* 4 *seed rates) : E.* 55 : *Lane Field. Sown May 29th,* 1924.

Species.	Percentage establishment of viable seed.		1st harvest year establishment with seeding year at 100.
	1924 (August).	1925 (August).	
Perennial rye-grass	45.1	43.5	96
Italian rye-grass	41.0	27.7	65
Cocksfoot	15.8	7.9	50
Timothy	17.4	7.4	43
Tall oat grass	17.8	9.4	53
Meadow fescue	16.5	17.4	105
Tall fescue	32.7	32.1	98
Montgomery red clover	37.3	47.5	127

These data unmistakably point to the occurrence of latency and of delayed germination—a phenomenon which appears to be more general than has hitherto been fully realized. Delayed germination cannot always be detected by comparing the results of sequential sward analyses, as the increase in number of plants consequent upon latency and delayed germination may be more than counterbalanced by the decrease due to heavy casualties in the plant population. The phenomenon, however, can be frequently detected in many species and notably in the fescues and in wild white clover. The present experiment stands as an instance where latency and delayed germination have been clearly shown in the case of a strain of late flowering red clover. The indications from other experiments are that seed latency is promoted by adverse conditions.

(3) *Effect of Competition upon Height of Timothy* (1925 *hay*).

Observations at the pre-flowering stage in timothy relative to the height to ligule of the upper fully opened leaf have been made, and the results are summarized in Table XIII. Ten readings were taken on each plot and the plots have been averaged on the basis of the various seed rates, whilst the influence of the rye-grasses individually and of other grasses in the aggregate is also shown.

Increasing the seed rate has caused a proportional decrease in the average height to ligule in timothy ; heavy seedings, with the consequent keener competition, therefore, decrease the vigour of individual plants in the sward.

Comparing the influence of the several species upon vigour, as measured by height to ligule, Italian rye-grass has the most pronounced effect, whilst the influence of perennial rye-grass is not so great.

TABLE XIII.—*Showing the average height in cms. to the ligule of the uppermost leaf of timothy sown with and without rye-grass : measurements made May 21st, 1925—pre-heading stage of timothy : E. 55. Lane Field.*

Seed rate of aggressor species.	Timothy.			
	With Italian rye-grass and red clover.	With perennial rye-grass and red clover.	With red clover only.	Average of 93 plots.
Rate 1 (basal rate)	5.0	6.6	6.8	6.2
,, 2 (1 x 2)	4.3	6.3	6.1	6.1
,, 3 (1 x 4)	4.2	5.5	5.5	6.3
,, 4 (1 x 6)	3.7	4.7	5.6	5.8
Average	4.3	5.8	6.0	6.1
Relative heights	72	97	100	

Tincker (22) in his physiological experiments has found that shortening the daily duration of daylight causes grasses, among other plants, to make a more stunted growth than the normal. It appears probable that the net effect of the competitive influences exercised by rapidly developing species is one of shading—the intensity of illumination reaching the smaller species is thus considerably decreased.

E. 55 : Summary to the Experiment.

(1) The yield and power to establish of the larger grasses varies considerably on contrasting types of soil. The rye-grasses appear to be very elastic in adapability. Tall oat grass on the clay soil of the experiment has been a comparative failure, whilst tall fescue has taken exceptionally well.

(2) Increasing the seed rate tends to depress percentage soil establishment and to lower the gross yields. Increasing the seed rate of aggressor species in a seeds mixture has a more depressant effect upon the non-aggressor species than upon the aggressors themselves.

(3) Direct evidence of delayed germination and/or of delayed development was found in meadow fescue and Montgomery red clover.

(4) Increasing the amount of competition exerted by aggressor grasses decreases vigour in timothy as measured by height to upper ligule in the pre-shooting stage.

E. 74: SEEDS MIXTURE EXPERIMENT TO TEST COMPETITIVE INFLUENCES UNDER WELSH UPLAND CONDITIONS: SOWN 1926.

Evidence from the trials so far discussed in this and in the previous paper has shown that the rye-grasses have an adverse influence upon the soil establishment and upon the productivity of other species sown in the seeds mixture. The majority of these experiments have been carried out at lowland centres, the more critical of them being conducted at the Plant Breeding Station farm. As it was highly desirable to test in some detail the findings of the lowland trials under the more exacting conditions of a typical Welsh hill farm, the present trial was laid out on an exposed upland farm.

Material and Methods.

The experiment, consisting of 15 seeds mixtures in 45 1/200th acre plots, was sown on April 30th, 1926, at Pensarn, situated about 700 ft. above sea level. The soil was poor and very stony; the field having been put through the rotation usual in the locality was seeded down to grass in 1926, barley being used as a nurse crop. The experimental area was reasonably uniform in general character. Details of the experimental seeds mixtures are given in Table XIV: a basal seeding of red, alsike, and wild white clovers was sown throughout in the mixtures. Meadow fescue and an indigenous and a commercial strain of cocksfoot were also brought under test, while the rye-grasses, sown both individually and together, were included in respective mixtures to function as "aggressor" species.

Accurate plant counts were made on the plots in mid-September, 1926—10 readings being taken per plot with the usual mesh. The percentage establishment of viable seeds was calculated for the grasses. The plots were grazed lightly by cattle and sheep during the winter and spring of 1926-27, and the field "put up" for hay in April, 1927. Representative samples of the standing hay crop on each plot were taken on July 15th, 1927—a date approximating to the normal time of cutting hay in the district—and the percentage productivity of the constituent sown species was estimated.

Discussion of Results.

(*a*) *The Influence of the Rye-grasses upon the Soil Establishment of Meadow Fescue and Cocksfoot.*

The data relative to establishment are given in Table XV, from which it will be seen that as a result of adding either or both of the rye-grasses to the seeds mixture there has been a marked decrease in the seeding year establishment of meadow fescue and of cocksfoot. It is of interest to note that meadow fescue has suffered to a greater relative extent than either of the two strains of cocksfoot

TABLE XIV.—*Showing the seeds mixtures sown in lb. per acre at real value=*100. *E.* 74 I: *Pensarn: sown April* 30*th*, 1926.

Number of mixture	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Meadow fescue	20	10	10	10	10	..	..	..	..	..	..	..	..	..	..
Cocksfoot (commercial)	..	..	..	..	..	20	10	10	10	10	..	..	..	..	..
Cocksfoot (indigenous)	..	..	..	..	..	..	..	..	..	..	20	10	10	10	10
Perennial rye-grass ..	..	10	..	10	..	..	10	..	10	..	..	10	..	10	..
Italian rye-grass ..	..	..	10	10	..	..	..	10	10	..	..	..	10	10	..
Montgomery red clover	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Alsike clover	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Wild white clover ..	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

—a result that is fully in accord with those obtained in similar trials carried out at the Station. Commercial cocksfoot has not been so strikingly affected in this, its seeding year, as has the more slowly developing indigenous strain. Growth being less rapid on upland than on lowland farms, it is only to be expected that the effect of competition from rye-grass and similar plants of relatively rapid development is correspondingly less great on the former, especially during the seeding year. Species such as meadow fescue, which are, however, highly sensitive to competition, are, as on the lowlands, easily suppressed when grown under competitive conditions with aggressor species. It will be seen that the addition of 20 lb. per acre of rye-grass to the basal seeding has markedly reduced average establishment of the three grasses.

The wide contrast between the percentage establishment of the two strains of cocksfoot in the seeding year is notable, and is in agreement with data previously obtained at the Station. Notes taken on the plots in 1927—the first harvest year—would seem to indicate that much delayed germination had taken place on the indigenous cocksfoot plots. Unfortunately it was not found possible to carry out a statistical analysis (counts) in the first harvest year, but the plots certainly gave the impression that they carried a greater number of plants per unit of area in the first harvest year than in the seeding year, and this was most marked in respect of indigenous cocksfoot.

TABLE XV.—*Showing* (1) *the percentage establishment of viable seed in meadow fescue and cocksfoot*; (2) *the influence of rye-grasses upon establishment on a Welsh hill farm*: (*seeding year* 1926): *E.* 74. I. *Pensarn.*

Particulars of rye-grass seeding: amounts in lb. per acre.	No rye-grass.	Perennial rye-grass 10.	Italian rye-grass 10.	Perennial & Italian rye-grass 10+10
Meadow fescue	42.4	19.9	21.3	16.7
Cocksfoot (commercial)	59.9	47.7	58.3	53.8
Cocksfoot (indigenous)	23.1	22.9	14.5	11.5
Average establishment	41.8	30.2	31.4	27.3
Relative establishment	100	72	75	65

(*b*) *Influence of the Rye-grasses upon the Productivity of Other Species as Hay.*

Table XVI shows the percentage productivity in the hay of the several constituents of the seeds mixture. The average productivity of meadow fescue and of the two strains of cocksfoot is given to make clear the effect of competition upon them: results for the three clovers are summated for a similar purpose. The data given permit of the following conclusions:—

(1) The rye-grasses have lowered the productivity of the other grasses and of the clovers in the hay of the first harvest year.

(2) Italian rye-grass is more aggressive in this respect than perennial rye-grass, and if both the rye-grasses are sown the productivity of the other species in the mixture is lowered still further.

TABLE XVI.—*Showing* (1) *the percentage productivity of certain grasses and clovers in hay at a Welsh hill centre* ; (2) *the influence of competition on hay in the first harvest year* (1927). *E.* 74. I. *Pensarn.*

Particulars of rye-grass seeding: amounts in lb. per acre.	No rye-grass.	Perennial rye-grass. 10	Italian rye-grass. 10	Perennial and Italian rye-grasses 10 + 10.
Meadow fescue	24.0	6.0	2.5	1.5
Cocksfoot (commercial)	19.8	8.5	3.5	4.5
Cocksfoot (indigenous)	19.0	4.5	7.5	1.5
Average productivity of the three grasses	21.1	6.3	4.4	2.5
Montgomery red clover	55.1	50.2	47.0	42.0
Alsike clover	14.7	9.5	11.7	12.0
Wild white clover	0.6	0.5	1.0	0.5
Total productivity of the three clovers	70.4	60.2	59.7	54.5

Observations made on the standing hay crop show that one further competitive effect of the rye-grasses was to reduce the number of panicle producing shoots in both meadow fescue and cocksfoot.

The results given indicate that conclusions already arrived at in relation to the competitive influence of the rye-grasses upon other species apply equally to conditions in Welsh upland districts as to conditions at lower elevations.

It is often asserted that meadow fescue does not " take " well except on the better classes of soil ; the evidence, however, suggests that the establishment of this grass can be satisfactory under poor soil and environmental conditions. This, therefore, lends support to the view that the erratic behaviour of meadow fescue in regard to soil establishment is largely a function of the degree of competition exerted upon it by rye-grass and other aggressive species. The rye-grasses are capable of more rapid development from seed than are most other species of herbage plants, and the indications are that the relative advantage is more than retained by them on the upland as opposed to the lowland districts. Their relative competitive influence subsequent to the seeding year would, therefore, appear to be as great as, or perhaps greater than, that found at lowland centres. Some light is therefore thrown upon sward development on Welsh hill farms. The rye-grasses are not persistent under these conditions, and as a consequence of their aggressive nature during the first harvest year they weaken, or actually kill, the more persistent elements of the seeds mixture. When heavy seedings of rye-grass are sown, these species, however, afford a valuable contribution to winter and spring keep, but by retarding the development of slower growing and more persistent species thay may do considerable harm, because the overwintering of the thus weakened seedlings of these latter species is impaired—effects which are aggravated by adverse climatic conditions coupled with the severe grazing practised on hill farms during the lambing periods. " Seeds " in the first harvest year normally provide fairly good hay crops, but persistency into the second harvest year is always poor; the sown plants giving place to weeds and other unsown species : the fall in

productivity from the first to the second harvest year is in consequence very heavy under these conditions.

Rapid development from seed coupled with high persistency seem therefore to be essential qualities for species destined to be successful in sward production under upland conditions in Wales.

E. 74 : Summary to the Experiment.

(1) The rye-grasses depress the soil establishment and the yield of cocksfoot, meadow fescue, and the clovers. This evidence therefore confirms that given by similar trials on the Welsh lowland areas.

(2) Perennial rye-grass appears to be almost, if not quite, as aggressive as Italian rye-grass on the poorer situations. Under more fertile conditions the latter is undoubtedly the more aggressive.

(3) The indications are that in the absence of the rye-grasses meadow fescue " takes " well on land of poor fertility. The assertion has often been made that meadow fescue will only establish itself on good soils, and while this generalization may not be strictly true, meadow fescue is undoubtedly a plant of high fertility requirement. Its fickleness of " take " may well, however, bear a close correlation to the presence or absence of rye-grass in the seeds mixture.

E. 63 : EXPERIMENT TO TEST THE SOIL ESTABLISHMENT OF MEADOW FESCUE IN PURE PLOTS AND IN SEEDS MIXTURES UNDER COMPETITIVE CONDITIONS : PENGLAIS FIELD. SOWN 1925.

Meadow fescue was sown in pure plots at four contrasting seed rates and in seeds mixtures with or without rye-grass, but again at differential rates of seeding.

Material and Methods.

The experiment was laid out on the Penglais Field, on a uniform but very poor piece of ground—the soil being thin and stony. Twelve mixtures in 48 1/400th acre plots were sown on May 1st, 1925, without a nurse crop : details of the seedings are given in Table XVII. The " take " of seeds was satisfactory, but the productivity was unfortunately poor, and for this reason the experiment was completed after taking hay, which was cut in June, 1926, but not weighed, and therefore no yield data are available. The plots were periodically grazed by sheep during the autumn and winter of 1925-26, and were " put up " for hay about the middle of February, 1926.

Analyses of the number of plants of each sown species per standard area were made on the plots in July—August, 1926, and the percentage establishment of viable seed has been calculated accordingly.

TABLE XVII.—*Showing the seeds mixtures in lb. per acre (real value=100) : sown May 1st, 1925 : E. 63 : Penglais Field.*

Number of mixture	1	2	3	4	5	6	7	8	9	10	11	12
Species.												
Perennial rye-grass	..	..	..	..	..	..	..	..	8	8	8	8
Meadow fescue	8	15	20	30	2	6	12	18	2	6	12	18
Cocksfoot	..	..	..	..	8	8	8	8	8	8	8	8
Timothy	..	..	..	..	4	4	4	4	4	4	4	4
Late-flowering red clover (Cotswold)	..	..	..	..	4	4	4	4	4	4	4	4
Wild white clover	..	..	..	..	½	½	½	½	½	½	½	½
Total seeding in lb. per acre	8	15	20	30	18½	22½	28½	34½	26½	30½	36½	42½

TABLE XVIII.—*Showing the average percentage establishment of viable seed in the first harvest year for meadow fescue and other species; field trials* 1926: *sown* 1925: *E.* 63: *Penglais Field.*

Plot number ..	1	2	3	4	5	6	7	8	9	10	11	12	Average. Plots 1—4 meadow fescue only.	Average. Plots 5—8 meadow fescue with basal mixture—no rye-grass.	Average. Plots 9—12 meadow fescue in full mixture with rye-grass.
Perennial rye-grass ..	..	..	..	..	..	..	..	..	48.0	50.9	41.8	35.7	..	..	44.1
Meadow fescue ..	64.7	44.5	38.4	28.7	37.5	35.0	35.8	22.4	13.3	21.9	6.7	8.4	44.1	32.7	12.6
Cocksfoot ..	..	..	..	..	21.0	25.6	22.4	22.9	23.4	24.6	19.3	23.1	..	23.0	22.6
Timothy ..	..	..	..	..	21.1	16.9	16.3	18.6	15.3	13.1	18.4	14.6	..	18.2	15.4
Late-flowering red clover ..	..	..	..	..	30.0	37.6	27.2	37.6	40.3	41.5	20.8	30.0	..	33.1	33.2
Wild white clover ..	..	..	..	..	16.0	21.6	24.6	25.9	27.2	46.2	34.5	27.2	..	22.0	33.8
Relative establishment of meadow fescue (plot 1=100) ..	100	69	59	44	58	54	55	35	21	34	10	13	100	74	29

Discussion of Results.

The Percentage Establishment of Viable Seed.

The average data in respect of establishment have been brought together in Table XVIII. The results for meadow fescue when sown in pure plots (cf. plots 1—4) show that an increase of seed rate has caused a reduction in the percentage establishment of viable seed, and thus indicate that pronounced interference with establishment has been caused by competitive inter-play occurring within the species itself. When seeded with a basal mixture containing cocksfoot, timothy, and the clovers (plots 5—8), the effect of seed rate of meadow fescue upon its own establishment is not apparent except at the heaviest seeding of 18 lb. per acre. Competition exerted by the basal mixture has exercised a considerable reduction on the establishment of the fescue when compared to the pure plots of this grass. The addition of perennial rye-grass to the basal mixture (plots 9—12) has effected a still more marked reduction in the soil establishment of the fescue.

The establishment of the other grasses and clovers, however, has not on the average been greatly reduced by the presence of the rye-grass ; this is not surprising when the poor growth conditions of the experiment are considered. The data, however, have demonstrated that meadow fescue reacts very definitely to quite small changes in the competition complex of the sward, and its percentage establishment is very easily depressed either as a result of increasing its own seed rate or of including it in seeds mixtures with species of more rapid development. Perennial rye-grass, for example, is highly aggressive. The summary figures at the end of Table XVIII are instructive ; they show that on the average the relative soil establishment of meadow fescue has been reduced from 100 (in pure plots) to 74 with a basal mixture of grasses and clover (excluding rye-grasses), and to 29 where perennial rye-grass has been added. The inclusion of perennial rye-grass has also tended to lower the establishment of cocksfoot and timothy, whereas no such evidence exists in relation to the clovers. It should be pointed out that in view of the small seeding, and therefore the relatively few plants, of wild white clover, the figures for this species may be liable to some considerable experimental error. Wild white clover was indigenous to the experimental area, and this factor would further militate against the reliability of the result in respect of this clover.

E. 63 : Summary to the Experiment.

(1) Increasing the rate of seeding in pure plots of meadow fescue reduces the percentage establishment of the viable seed sown.

(2) The percentage establishment of meadow fescue is less satisfactory when seeded in mixtures with cocksfoot, timothy, and red clover than when sown in pure plots. The addition of perennial rye-grass has a still greater depressant action upon establishment.

(3) Whilst meadow fescue has shown the greatest reaction to the competitive influences of perennial rye-grass, timothy and cocksfoot have each given definite reactions. Under the conditions of the experiment (which was notable for its low productivity both in the seeding and first harvest years) the establishment of red clover was not affected by perennial rye-grass.

E. 34: SEEDS MIXTURE EXPERIMENT TO TEST THE EFFECT OF THE LARGER GRASSES UPON THE YIELD AND PERSISTENCY OF OTHER GRASSES AND CLOVERS: WOOD FIELD. SOWN 1923.

Material and Methods.

This experiment, consisting of 10 seeds mixtures in 35 1/100th acre plots, was sown on June 15th, 1923, on Wood Field without a nurse crop. The soil, a light loam, was rather shallow, but of reasonable uniformity. A dressing of basic slag at 6 cwt. per acre was given before sowing, but no manures were applied after the commencement of the trial. Details of the seeds mixtures are given in Table XIX, from which it will be seen that the experiment allows of a study of the competitive influence of the rye-grasses and cocksfoot upon meadow fescue, meadow foxtail, sweet vernal grass, and the clovers.

TABLE XIX.—*Showing the seeds mixtures in lb. per acre (no adjustment for real values): E. 34: Wood Field. Sown June 15th, 1923.*

Species.	Number of mixture.									
	1	2	3	4	5	6	7	8	9	10
Italian rye-grass ..	..	7	..	..	..	7	..	..	..	..
Perennial rye-grass ..	..	..	7	..	..	..	7	..	..	10
Cocksfoot	..	..	..	7	..	..	..	7	..	..
Meadow fescue ..	14	7	7	7	..	..	..	..	..	..
Meadow foxtail ..	..	..	..	..	14	7	7	7	..	..
Sweet vernal grass ..	..	..	..	..	..	..	..	..	10	5
Late flowering red clover	4	4	4	4	..	..	..	..	..	..
Broad red clover ..	..	..	..	..	4	4	4	4	..	..
Wild white clover ..	..	..	..	..	..	..	..	..	4	4

Crops of hay and aftermath were taken in the first harvest year, but hay only was taken subsequently—the aftermath being grazed by sheep. The hay crops of each year and the aftermath of the first harvest year were cut, weighed, and sampled by the usual method: the samples were botanically analysed into their constituent sown species and weeds.

Botanical analyses were also conducted on the ground after removal of the hay crop each year. On every plot, plants of the sown species occurring within 10 mesh readings (6 inches by 6 inches) taken at random were recorded, and by this means it has been possible to make a comparative statement relative to the persistency of those species during the four years through which the experiment was carried.

Discussion of Results.

(*a*) *Yields of Hay in Sown Species. Comments on Tables* XX, XXI, *and* XXII.

Table XX gives the air-dried hay yields obtained from the several species in each mixture during the first harvest year, while Table XXI gives the comparable data taking the aggregate of the first four harvest years 1924 to 1927

TABLE XX.—*Showing the first harvest year yields of air-dried hay in cwt. (= 100 lb.) per acre: 10 seeds mixtures: 1924, first harvest year. E. 34. Wood Field.*

Species.	Number of mixture.									
	1	2	3	4	5	6	7	8	9	10
Italian rye-grass ..	..	37.3	..	..	..	35.6	..	..	..	..
Perennial rye-grass ..	..	..	43.8	..	..	..	36.8	..	..	21.7
Cocksfoot	..	..	..	19.0	..	..	..	18.5	..	..
Meadow fescue ..	30.0	3.5	4.9	17.6	..	..	..	..	..	..
Meadow foxtail ..	..	..	..	..	12.7	2.7	5.3	5.5	..	..
Sweet vernal grass ..	..	..	..	..	..	..	..	..	34.7	15.1
Late flowering red clover	49.3	33.6	33.3	42.9	..	..	..	..	..	..
Broad red clover ..	..	..	..	..	26.6	20.4	23.7	34.2	..	..
Wild white clover ..	..	..	..	..	..	..	..	..	3.7	4.8
Weeds (= unsown plants)	28.4	12.7	14.6	24.5	21.7	11.7	14.8	20.6	20.0	24.0
Total	107.7	87.1	96.6	104.0	61.0	70.4	80.6	78.8	58.4	65.6
Relative	100	81	90	97	100	115	132	129	100	112

inclusive. The two tables may be considered together. Having regard to competition in the first year, it is shown that Italian rye-grass is more aggressive than perennial rye-grass, and the latter in turn is more aggressive than cocksfoot, both in relation to the sown grasses (meadow fescue and meadow foxtail), and to a lesser degree in relation to the two strains of red clover. Similar relation-

TABLE XXI.—*Showing the total yield of air-dried hay over the first four harvest years: 10 seeds mixtures: 1924—1927: E. 34: Wood Field.*

Species.	Number of mixture.									
	1	2	3	4	5	6	7	8	9	10
Italian rye-grass ..	..	47.5	..	..	..	41.8	..	..	..	..
Perennial rye-grass ..	..	..	74.9	..	..	..	57.1	..	..	45.3
Cocksfoot	..	..	..	73.4	..	..	..	50.3	..	..
Meadow fescue ..	75.2	15.0	16.8	33.0	..	..	..	..	..	..
Meadow foxtail ..	..	..	..	..	49.3	28.2	34.7	34.0	..	..
Sweet vernal grass ..	..	..	..	..	..	..	..	..	69.6	48.1
Late flowering red clover	85.2	71.5	64.0	72.8	..	..	..	..	..	..
Broad red clover ..	..	..	..	..	27.3	22.2	25.5	34.8	..	..
Wild white clover ..	..	..	..	..	..	..	..	..	15.3	17.1
Weeds (= unsown plants)	133.2	123.9	114.2	98.0	90.5	82.9	75.0	72.0	73.4	57.8
Total	293.6	257.9	269.9	277.2	167.1	175.1	192.3	191.1	158.3	168.3
Relative	100	88	92	94	100	105	115	114	100	106

ships appear to exist between the aggressor sown grasses and the weeds, whilst perennial rye-grass is definitely aggressive in the first year towards sweet vernal grass.

Competition is naturally most marked in effect during the year that follows seeding ; the herbage at this time is composed of plants having widely different growth habits. Comparison of the data presented in Tables XX and XXI further shows that the influence of first year competition is extended into the subsequent harvest years, and has a considerable influence upon the total yield given by the sown species over the four harvest years.

Certain species are better able than others to make recovery in yielding powers following the initial setback consequent upon the intense competition of the first year. For whereas their primary establishment may have been low, they are able, by virtue of a favourable characteristic in growth-form, to spread when competition becomes less severe. Stoloniferous plants thus generally make recovery to some considerable degree from the adverse effects of first year competition. ' Spot bound ' (usually caespitose) plants are not able to recover to so marked a degree, and their success is as a rule more intimately dependent upon good initial establishment. By adequate self-seeding, however, a spot-bound herbage plant may be enabled to make up leeway subsequent to the first harvest year.

Table XXII shows the hay yields in the fourth harvest year of the three " non-aggressor " grasses, and the data serve to illustrate the behaviour of species representing the three categories of plants to which allusion has been made.

TABLE XXII.—*Showing the hay yields of meadow fescue, meadow foxtail, and sweet vernal grass in the fourth harvest year when sown in mixtures without and with rye-grass or cocksfoot. The figures illustrate the influence of ' growth form ' upon fourth harvest year yields : cwt.* (= 100 *lb.*) *of air-dried hay. E.* 34. *Wood Field,* 1927.

Aggressor species.	Without rye-grass.	Italian rye-grass.	Perennial rye-grass.	Cocksfoot.
Meadow fescue	(1)* 15.5	(2) 7.8	(3) 7.8	(4) 6.0
Meadow foxtail	(5) 11.7	(6) 13.2	(7) 13.5	(8) 7.9
Sweet vernal grass	(9) 13.3	..	(10) 14.5	..

* Figures in brackets show number of seeds mixture—see Table XIX.

Meadow fescue is an example of a ' spot-bound ' species having a relatively poor capacity for re-establishment by self-seeding, and it therefore fails to make recovery in cropping power during the later harvest years after subjection to competition from the rye-grasses during the first year after sowing. Sweet vernal grass is a profuse self-seeder, and moreover is a species which, by virtue of flowering early in the season, is able to set and shed its seed crop before the normal date of cutting hay. In the present case the plots were cut for hay

about the middle of June in each year: the earliest grasses had therefore set seed, whilst the rye-grasses, cocksfoot, and meadow fescue were only exserting their anthers; sweet vernal grass had each year, however, shed a proportion of its seed before the plots were cut.

The third category is here represented by meadow foxtail, a grass which is appreciably stoloniferous, but one which is normally shy in flower production, although it may throw up inflorescences very early in the spring. Re-establishment by self seeding is, however, probably not extensive in meadow foxtail. Table XXII indicates that meadow foxtail was able to spread most rapidly on the 'with rye-grass' plots, largely because the rye-grasses were less vigorous than cocksfoot after the first year and so were relatively less aggressive towards the foxtail. It is therefore probably significant that the fourth year hay yields from sweet vernal grass and from meadow foxtail are highest in the 'with rye-grass' mixtures, although both species in common with meadow fescue were suppressed by the rye-grasses during the first harvest year. Cocksfoot is relatively aggressive in the later years and is shown to have largely prevented the recovery in yield of meadow foxtail, whilst a similar conclusion is indicated by the data for meadow fescue (Table XXII).

Where the basal seeds mixture consists of species which are non-aggressors but which are calculated to make for heavy first year hay yields, the addition of highly aggressive species is likely to reduce the total yield of hay. Table XX shows, for example, that the gross hay yield from mixture 1—containing meadow fescue and late red clover, both species of high potential yielding capacity in hay—is appreciably higher than in mixtures 2—4 where rye-grass or cocksfoot was added. The extra yields given by the aggressor species do not in these cases make full compensation for the loss in yield of non-aggressor species (namely, the fescue and the late red clover), consequent upon competition. In cases where the yield of non-aggressors is likely to be low in the first year, as, for example, in the slow developing meadow foxtail, the addition of more rapidly growing species may increase the gross yields though still reducing the yields of the "non-aggressors."

The comparatively low hay yield of cocksfoot in the first harvest year is noteworthy. In that year its yield of hay is less than half the average first year yields of the rye-grasses, whilst over the four years cocksfoot has considerably outyielded Italian rye-grass and has about equalled perennial rye-grass. It needs to be emphasized, however, that the hay yield of cocksfoot is relatively low in comparison with its total annual yield, a very large proportion of the total being produced during late summer. The relatively heavy yield of meadow fescue as a hay grass marks it as a species of considerable utility for this purpose, but one which is especially sensitive to the sum of the influences of the competition complex.

The relative yields of English late-flowering and of English broad red clovers are important, and the figures show the vast superiority of the late strains even in the first harvest year, whilst the difference is far more marked in the aggregate of three or four years.

(*b*) *Yield per Plant in Hay. Comments on Tables* XXIII *and* XXIV.

Table XXIII shows the average air-dried weights per plant for the several sown species during each of the four harvest years in so far as reliable data are available. Yield per plant in hay appears to be at its maximum in the

TABLE XXIII.—*The average weight per plant as hay in the sown species: milligrammes per plant, air-dried weights: first to fourth harvest years* 1924—1927: *E.* 34. *Wood Field.*

Species.	Harvest year.			
	1st 1924.	2nd 1925.	3rd 1926.	4th 1927.
Italian rye-grass	4,760	3,210	436	1,446
Perennial rye-grass	6,390	3,215	1,005	1,688
Cocksfoot	3,630	2,220	1,384	1,367
Meadow fescue*	4,890	2,410	569	747
Meadow foxtail*	1,560	970	960	..
English late flowering red clover* ..	12,500	13,900	4,670	4,675
English broad red clover*	7,410	2,230	..	..
Sweet vernal grass*	3,820	..	..	..
Wild white clover*	600	..	..	..
Average of the five species where data for the four years are available†	6,434	4,991	1,613	1,985
Relative, 1st harvest year 100 ..	100	78	25	31

* Data obtained from plots sown without the aggressor grasses, *viz.*, rye-grass or cocksfoot.
† Italian rye-grass, perennial rye-grass, cocksfoot, meadow fescue, meadow foxtail, and English late flowering red clover.

first harvest year; there is a considerable falling off in the second year, and the data show a still more marked decline in the third year, with a slight recovery in the fourth year. The slight increase in the average figure for 1927 as compared to 1926 is probably connected with an increase in number of established plants, consequent upon latent seeds springing into activity.

A large number of the plants (those derived from latent seed) would virtually be in their first harvest year in 1927 and therefore at their period of maximum productivity. Delayed germination will receive further detailed consideration.

TABLE XXIV.—*Showing the influence of rye-grass and cocksfoot upon the yield per plant over four harvest years* 1924—1927 *given by meadow fescue, meadow foxtail, and late flowering red clover: air-dried weights of hay in milligrammes per plant: E.* 34: *Wood Field.*

Species.	Meadow fescue.	Meadow foxtail.*	Late flowering red clover.	Total and relative.
Without rye-grass or cocksfoot ..	8616	3000	35.745	47.361 (100)
With rye-grass only	6204	2056	25.239	33.499 (71)
With cocksfoot only	7103	3320	25.055	35.478 (75)

* Totals for three years only in respect of meadow foxtail: no data for this species available in 1927.

The aggregate yields per plant as hay for the four harvest years are given in Table XXIV in respect of meadow fescue, meadow foxtail, and late flowering red clover. The data illustrate that the rye-grasses and cocksfoot are able to depress vigour in the less aggressive species. In general, the rye-grasses during the first years are considerably more aggressive than cocksfoot, but the data indicate that cocksfoot may in some cases be highly aggressive towards red clover, an observation also made by Lindhard (14) as a result of his Danish experiments: the data in the present trial are not, however, wholly conclusive in this connection. Cocksfoot does not appear to be very aggressive towards non-aggressor grasses during the first year, but its relative aggressiveness increases in subsequent harvest years, especially under continual hay conditions.

TABLE XXV.—*Showing* (1) *the average number of plants of the sown species occurring per unit of area* (= 2½ *sq. ft.*), *in each of the four consecutive harvest years* 1924—1927; (2) *the aggressive influence of the larger grasses upon other grasses and the clovers*: *E.* 34: *Wood Field.*

Aggressor grass and reference number to mixture.	— (1)	Italian rye-grass. (2)	Perennial rye-grass. (3)	Cocksfoot. (4)	— (5)	Italian rye-grass. (6)	Perennial rye-grass. (7)	Cocksfoot. (8)
	Plants of meadow fescue.				*Plants of meadow foxtail.*			
Harvest years 1924	50.7	5.7	12.0	34.0	67.5	27.8	38.5	47.2
Harvest years 1925	45.3	8.8	16.0	20.3	95.5	69.0	63.0	52.0
Harvest years 1926	75.3	24.0	25.5	26.3	67.3	42.0	52.5	34.5
Harvest years 1927	54.0	23.5	20.8	20.0	..*	..	..	..

Aggressor grass and reference number to mixture.	— (1)	Italian rye-grass. (2)	Perennial rye-grass. (3)	Cocksfoot. (4)		— (9)	Perennial rye-grass. (10)
	Plants of late flowering red clover.				*Plants of sweet vernal grass.*		
Harvest years 1924	32.6	23.2	23.6	27.4	..	75.0	46.6
Harvest years 1925	8.8	15.5	12.8	11.8	..	..	..
Harvest years 1926	9.3	11.0	11.0	11.0	..	..	..
Harvest years 1927	2.5	0.8	1.8	3.5	..	..	..

Reference number to mixture	Plants of Italian rye-grass. (2)	Plants of perennial rye-grass. (3)	Plants of cocksfoot. (4)
Harvest years 1924	63.2	51.7	41.0
Harvest years 1925	14.8	30.8	40.3
Harvest years 1926	14.3	21.5	41.8
Harvest years 1927	1.8	17.3	37.3

* Accurate plant counts not possible for meadow foxtail in its fourth year.

(c) Delayed Germination. Comments on Table XXV.

Table XXV gives the average number of plants occurring per unit of area* with respect to the chief sown species and in each of the four harvest years 1924—27. The intensity of sward competition presented a wide contrast on the different plots, particularly during the growth periods of the seeding and of the first harvest years. The yield data discussed above have indicated that competition was at the maximum on plots with the rye-grasses in the seeds mixture, and, conversely, was least where the rye-grasses were excluded from the mixture.

Considering the results brought forward in Table XXV in respect of meadow fescue, it is seen that in the first harvest year Italian rye-grass has, as usual, depressed the establishment of the fescue, and has been more aggressive than either perennial rye-grass or cocksfoot. These data are confirmed by the readings made again in the second harvest year. In the third and fourth years the number of meadow fescue occurrences (in plots 2—4) have been largely levelled up. The important point, however—and one wholly unlooked for at the commencement of the trial—is that *well marked increases* in the number of fescue plants occur subsequent to the first harvest year ; these increases are greatest where the competition in the first year was most intense. The figures are not liable to heavy experimental error, due attention having been paid to accuracy of sampling and of technique. It should be emphasized, for example, that no self-seeding was allowed to take place on the plots except in sweet vernal grass and to a less extent possibly in meadow foxtail—both these grasses seed very early in spring. No seed setting occurred in the rye-grasses, meadow fescue, cocksfoot or red clover.

The data therefore show undoubted evidence of delay or latency either in the germination of sown seed or in the development of the young seedlings. There is no evidence available to show the proportions in which these two phenomena may have occurred, but on a *priori* reasoning it might be supposed that the critical seedling stages would not prove highly suitable to carry over a prolonged period of delayed growth. It appears likely, therefore, that the increase in plant numbers found in the second and subsequent harvest years is primarily the result of delayed germination. Stapledon, Davies and Beddows (21) have shown that certain species dealt with in garden trials gave evidence during the seeding year both of delayed germination and of delayed development (= arrested growth of seedlings). Adverse conditions, both climatic and agronomic, were found to increase the tendency to delayed development, and it was shown that grass seeds may lie dormant for considerable periods in the soil without rotting, to show germination when conditions improve.

The results from the garden experiments seem to be amply confirmed by the field results now under consideration. The increase in numbers of meadow fescue plants—and therefore the amount of delayed germination and/or of arrested development of seedlings—has been greatest under conditions of greatest *'adversity'*, namely, where competition was most intense during the first harvest year. Growth conditions on these plots, having due regard to competition, did not improve until the second harvest year, when the rye-grasses, as aggressor species, had largely died back. In the second and third harvest years, therefore, large increases in numbers are found in the non-aggressor grasses, and

* 2½ sq. ft. (= 10 readings by the 6 inch × 6 inch mesh).

this is especially marked on the "with-rye-grass" plots. It is tentatively suggested, therefore, that these increases are mainly due to delayed germination, and that conditions of intense competition, in so much as they are 'adverse conditions', tend to increase delayed germination in herbage plants. Further experiments in connection with these problems have been started at the Station, but much critical work will be needed to elucidate the factors that affect the closely related phenomena of delayed germination and delayed growth in seedlings.

There are decided indications that the soil moisture content, the circulation of air, and the intensity and duration of daylight have a considerable influence upon the rapidity of soil germination in herbage plants. Excessive moisture and reduced illumination, as a consequence of intense sward competition or following late autumn sowings, appear to favour latency. Kidd (11) found that increased concentrations of carbon dioxide in the atmosphere tended to have a depressant action on germination. It would appear to follow that it may well be that active root development, by causing the production of a soil atmosphere rich in carbon dioxide, makes for conditions likely to encourage latency in seed. It is possible that along these lines may ultimately be found the explanation why charlock and other seeds remain dormant on old pastures. The mat of more or less actively growing roots coupled with a poor system of soil aeration may help to prolong the period of latency in the seed. Ploughing breaks up the mat of roots, helps to aerate the soil, and promotes conditions more favourable to the germination of seed.

E. 34 : Summary to the Experiment.

(1) During the first year of the ley the rye-grasses are more aggressive towards other species than is cocksfoot. As the rye-grasses tend to die back earlier than cocksfoot, the latter is comparatively more aggressive in the later harvest years.

(2) Cocksfoot appears to be fairly aggressive towards red clover, meadow fescue, and meadow foxtail.

(3) Gross yield of hay is heaviest in the first harvest year, and it follows, since the influence of competition is also greatest in the first year, that the depressant effect of aggressive species is marked in the aggregate results of four harvest years.

(4) There is evidence to show that arrested development—latency of seed or delayed growth of seedlings—may be an important factor in sward establishment. The phenomenon appears to be closely correlated with the intensity of competition during the first year after sowing.

E. 62 : SEEDS MIXTURE EXPERIMENT TO TEST THE INFLUENCE OF (1) SOWING DATE : (2) NURSE CROP, AND (3) THE RYE-GRASSES UPON ESTABLISHMENT AND YIELD. LANE FIELD. SOWN 1925.

This experiment deals with an important section of the agronomic work conducted at the Station in connection with the study of seeds mixture problems. It was originally designed to test three main points :

(1) The best date at which to sow seeds of herbage plants.

(2) The influence of a cereal nurse crop upon their establishment and yield.

(3) The effect of differential seedings of the rye-grasses upon the yield and botanical composition of the temporary ley.

This trial, therefore, deals with problems that have already been under exhaustive study at the Station, and is the outcome of the earlier tests which were largely conducted under garden conditions.

Material and Methods.

The experiment was laid out on the Lane Field, and although the main body of this field is inclined to be wet and not uniform, yet it was possible to choose areas which were both uniform and well drained, and, therefore, suitable for experimental purposes. The usual dressing of 6 cwt. per acre of high-grade slag was applied before sowing the seeds. Five seeds mixtures were sown in 150 1/400th acre plots : details of the seedings are given in Table XXVI, where it is shown that the fundamental difference between the several mixtures lies in the relative amounts of the rye-grasses.

TABLE XXVI.—*Showing seeds mixtures sown in lb. per acre (at real value* 100) : *sown* 1925 : *E.* 62 I—IV : *Lane Field.*

Species.	Number of mixture.				
	1	2	3	4	5
Perennial rye-grass	..	10	10	10	10
Italian rye-grass	..	..	2	6	18
Cocksfoot	8	8	8	8	8
Timothy	4	4	4	4	4
Meadow fescue	4	4	4	4	4
Meadow foxtail	4	4	4	4	4
Rough-stalked meadow grass ..	2	2	2	2	2
English late flowering red clover ..	4	4	4	4	4
Wild white clover	2	2	2	2	2
Total seeding in lb. per acre ..	28	38	40	44	56

The plots were put down in 1925 in four sections (designated parts I—IV) corresponding with four sequential sowing dates as follows :—

E. 62, part I, sown March 31st, 1925.
E. 62, ,, II, ,, April 24th, 1925.
E. 62, ,, III, ,, May 23rd, 1925.
E. 62, ,, IV, ,, August 19th, 1925.

At each of the first three sowing dates (parts I—III) the influence of a cereal nurse crop upon establishment and yield was tested, according to the plan set out hereunder ; this test was not extended to the August sowing, which was seeded without a cereal in every case.

Method A—nurse allowed to become dead ripe in accordance with normal farm practice.

,, B—nurse cut as a fodder crop : grain in " milky " stage.

,, C—without cereal or nurse of any kind.

Record oats sown at 160 lb. (= 4 bushels) per acre were used as nurse.

The corn crop was harvested and cleared from the plots during August and September, 1925 ; every plot was cut back by scythe whether sown with a cereal or not. Subsequently the experiment was grazed by sheep on an intermittent basis, and " put up " to hay on February 1st, 1926—hay and aftermath being taken in that year. Intermittent grazing by sheep was again carried on through the autumn and winter of 1926—27, and the plots " put up " to hay in early February, 1927 (the second harvest year) : the second year aftermath was grazed by mixed stock.

The produce from each plot was weighed in the green state directly upon cutting, and representative samples were taken in every case for botanical analysis and for dry weight estimation. In July, 1926, further botanical analyses were conducted on the ground, the herbage being studied *in situ* : the average number of plants per unit of area belonging to sown species was thereby found. Directly comparable data were obtained in 1927 by analysing turfs (6 inches by 6 inches) lifted from each plot.

From the data collected it has been possible to calculate the percentage establishment of viable seed for each sown species both in the first and second harvest years. The yields of the several species as well as the vigour of individual plants under the influence of different competitive influences have been calculated for the two-year period under review. Comparisons are made in respect of date, method and rate of sowing as they influence establishment, and also relative to gross yield and vigour in the several contributing species.

Discussion of Results.

(1) *Establishment.*

A considerable amount of data dealing with soil establishment in herbage plants has been published from the Station, and it has been shown (see Davies (5)) that in pure culture beds there is a positive correlation between the number of laboratory viable seeds used and the resultant number of plants established. Under normal field conditions only a proportion of the seed successfully produces mature plants : in general, the larger seeded species and strains establish themselves better from seed than do species with low grain weights (= small seeded species). The majority of the trials previously reported upon were conducted either on plots or in drills sown with only one species, or they were conducted with very simple mixtures where competition was not excessive.

The experiment now under review (E. 62) was conducted under a system of management which aimed at attaining to something like a maximum degree of competitive interaction between species of widely contrasting growth habits, while at the same time the practical aspect of the problems involved and the application of the results have always been given due consideration.

(*a*) *Influence of Sowing Date upon Soil Establishment.*

Previous work at the Station (conducted under conditions representative of the high rainfall areas of Britain) has shown that there is a fairly well defined range of sowing dates within which successful establishment of herbage plants may be expected. A few species, and in particular the rye-grasses, have a long sowing season, extending from early March to October, whereas the generality of species require to be sown not later than midsummer (see Stapledon, Davies, and Beddows (21)). The present trial has shown minor differences

TABLE XXVII.—*Showing the average percentage establishment of viable seed for the sown species in the first and second harvest years respectively: four contrasting sowing dates: E. 62 I—IV: Lane Field.*

Year	1926 first harvest year.					1927 second harvest year.				
Reference number	I.	II.	III.	IV.	Average	I.	II.	III.	IV.	Average
Month of sowing 1925	March.	April.	May.	August.		March.	April.	May.	August.	
Perennial rye-grass	26.2	40.2	41.2	43.2	37.7	12.3	13.8	16.0	21.1	15.8
Italian rye-grass	62.9	94.0	66.1	67.8	72.7	21.0	29.5	25.8	18.5	23.7
Cocksfoot	20.5	23.6	20.1	25.0	22.3	14.7	14.1	12.8	15.2	14.2
Timothy	7.4	8.5	6.4	3.5	6.5	6.3	9.0	8.9	7.8	8.0
Meadow fescue	23.2	27.0	23.3	7.6	20.3	18.1	23.7	26.7	15.9	21.1
Meadow foxtail	1.0	0.2	0.8	0.5	0.6	0.6	0.3	0.4	2.2	0.9
Rough-stalked meadow grass	7.3	5.7	6.4	5.8	6.3	13.9	13.7	11.6	12.1	12.8
Late flowering red clover	46.2	55.3	46.8	11.8	39.9	7.5	13.7	14.0	8.0	10.8
Wild white clover	16.8	20.4	20.4	13.8	17.9	..*	..	..	..	..
Average of all species	23.5	30.5	25.7	19.9	..	..	..	..	..	..
Average without Italian rye-grass and wild white clover	18.8	22.9	20.7	13.9	..	10.5	12.6	12.9	11.8	..
Average of cocksfoot, timothy, meadow fescue, rough-stalked meadow grass, and red clover	20.9	24.0	20.5	10.7	..	12.1	14.8	14.8	11.8	..

* Plant counts were not made in respect of white clover in the second harvest year.

between sowings made up to May, but in the majority of species the August sowing has given results that compare unfavourably with those made earlier in the year (see Table XXVII). The difference in relative establishment is greatest in the first harvest year and is most pronounced in the clovers, in meadow fescue, and in timothy : the evidence considered as a whole indicates however, that the majority of species give the best results when sown in spring.

In the second harvest year (1927), analyses conducted upon the same plots as in 1926 have shown that the differences in establishment found in the first harvest year in respect of the contrasting dates of sowing have largely levelled themselves out, and this is specially marked in meadow fescue, timothy, and the clovers. In all cases the casualties appear to have been greater on the spring as opposed to the August sown plots, while there are instances of actual increase in number of plants on the latter series. These instances occur in species that are normally of slow development from seed. The results are suggestive, and demonstrate that grass and clover seed can remain latent in the soil during the whole, or the larger part, of the first harvest year, and can later germinate to produce established plants in the second harvest year. The results, therefore, indicate that delayed germination can play an important rôle in the establishment of seeds mixtures. Brenchley (2) found that buried seeds belonging to a wide range of *Gramineae* and *Leguminosae* could remain dormant for prolonged periods and still retain their capacity for germination, whilst Dorph Petersen (8) has brought forward similar results obtained from artificially

TABLE XXVIII.—*Showing the comparative percentage establishment of viable seed (sown species) in a seeds mixture (1) if the nurse crop is cut ripe ; (2) if the nurse crop is cut as fodder ; (3) if sown without a cereal nurse : first and second harvest years : E. 62 : Lane Field.*

Year	1926 1st harvest year.			1927 2nd harvest year.		
Reference	A.	B.	C.	A.	B.	C.
" Nurse " crop.	Ripe oats.	Fodder oats.	No nurse.	Ripe oats.	Fodder oats.	No nurse.
Perennial rye-grass	39.2	34.4	35.3	14.7	13.5	15.9
Italian rye-grass	64.5	75.6	77.1	24.4	23.3	26.4
Cocksfoot	22.9	20.5	21.8	14.3	15.2	14.4
Timothy	7.3	7.1	6.9	8.2	7.9	8.0
Meadow fescue	19.9	21.4	27.0	19.0	23.5	24.0
Meadow foxtail	0.6	0.6	0.7	0.6	0.3	0.4
Rough-stalked meadow grass	7.1	6.2	5.3	15.6	13.0	12.9
Late flowering red clover	50.0	47.2	42.4	11.3	11.5	6.1
Wild white clover	20.4	17.9	18.0	..*	..	..
Average of all species	25.8	25.7	26.1	..	..	..
Average without wild white clover	26.4	26.6	27.1	13.5	13.5	13.5
Average of cocksfoot, timothy, meadow fescue, rough-stalked meadow grass and red clover	21.4	20.5	20.7	13.7	14.2	13.1

* Blanks indicate that no counts were made.

buried seeds. Lindhard (13) also in discussing some of Nilsson's early work has given evidence which clearly indicates that delayed germination of sown seed occurred in the case of the Danish trials.

(*b*) *Method of sowing having regard to Nurse Crop and its effect upon Soil Establishment.*

The average figures for all species given in Table XXVIII do not show wide variation consequent upon the three systems of "nurse" cropping.

The "take" of nurse was, however, not satisfactory, with the result that the young "seeds" made more vigorous growth in the seeding year than they would normally have done under a thicker crop of cereal. Under the circumstances it was not to be expected that considerable differences in establishment would occur as a result of the three methods, which, although purporting to be contrasting, were in many respects very similar. The influence of a nurse crop upon soil establishment has been somewhat fully discussed elsewhere*: the general effect of any nurse crop, after a certain growth stage is reached, is to retard the development of the "nursed" seedlings. If, however, a seeds mixture containing excessive seedings of rye-grass is sown without a nurse crop, the rye-grasses may, unless properly managed by controlled grazing, do definite harm to the general establishment of the young seeds and far more harm than a cereal crop is normally likely to do.

There are, however, indications in Table XXVIII that the oat crop has caused some reduction in establishment—the first year figures for meadow fescue show 19.9 : 21.4 : 27.0 per cent. for methods A, B and C respectively. Meadow fescue has in all trials been highly susceptible to competition, and any small change in management which affects the competition complex will at once modify the behaviour of this grass in respect of establishment.

(*c*) *Influence of the Rye-grasses upon Soil Establishment of other species.*

Soil establishment data for the present experiment in regard to the influence of perennial and Italian rye-grass have been summarized in Table XXIX. They show that the rye-grasses can exert an important influence upon the botanical composition of the herbage. In the first harvest year heavy seedings of rye-grass have been the means of lowering the percentage establishment in the majority of other species, but particular species are influenced to a greater extent than others. Meadow fescue, for example, is shown in 1926 to have had an average establishment of 51.2 per cent. without rye-grass (mixture 1) as compared to only 3.4 per cent. where excessive seedings of rye-grass were made (mixture 5). In a similar manner timothy has a corresponding figure of 12.0 per cent. on the one hand and only 2.6 per cent. on the other. The average figures for all species are instructive and demonstrate conclusively the influence of the rye-grasses.

Late red clover was erratic in behaviour, but the results show that the rye-grasses have not been able to depress its percentage establishment to a figure lower than that in mixture 1 (without rye-grasses). This would seem to lend support to the opinion held by Lindhard (14) that red clover is suppressed by cocksfoot. Much of the evidence accumulating at the Station indicates that cocksfoot is at least as aggressive as the rye-grasses towards red clover,

* See Stapledon and Jones, (18).

TABLE XXIX.—*Showing the effect of the addition of the rye-grasses at a number of seed rates upon the percentage establishment (of viable seed) in a seeds mixture: E. 62: Lane Field.*

Year	1926 first harvest year.				
Number of mixture*	(1)	(2)	(3)	(4)	(5)
Total rye-grasses in lb. per acre	..	10	12	16	28
Perennial rye-grass	..	52.5	33.4	32.1	27.9
Italian rye-grass	..	..	120.0†	62.3	37.0
Cocksfoot	28.3	25.2	21.6	16.9	14.9
Timothy	12.0	7.3	6.8	5.1	2.6
Meadow fescue	51.2	17.6	14.7	13.1	3.4
Meadow foxtail	1.0	1.0	0.3	0.7	0.1
Rough-stalked meadow grass	8.9	6.6	4.9	5.8	5.8
Late flowering red clover	43.9	47.9	43.8	48.6	52.5
Wild white clover	22.5	17.9	17.1	18.4	18.1
Average without rye-grasses and white clover	24.2	17.6	15.4	15.0	13.2
Average of cocksfoot, timothy, meadow fescue, rough-stalked meadow grass, and red clover	28.9	20.9	18.4	17.9	15.8
	1927 second harvest year.				
Perennial rye-grass	..	15.5	15.5	13.7	11.4
Italian rye-grass	..	..	41.3	19.5	12.2
Cocksfoot	15.1	15.3	14.3	12.8	11.6
Timothy	11.4	8.7	6.8	7.4	4.3
Meadow fescue	39.4	22.5	17.3	13.5	10.5
Meadow foxtail	0.8	0.5	0.9	0.8	0.4
Rough-stalked meadow grass	14.0	13.3	13.0	15.2	14.8
Late flowering red clover	7.0	12.2	12.2	10.8	16.2
Wild white clover	‡	..	..	..	..
Average without rye-grasses and white clover	14.6	12.1	10.8	10.1	9.6
Average of cocksfoot, timothy, meadow fescue, rough-stalked meadow grass, and red clover	17.4	14.4	12.7	11.9	11.5
Relative with 1926 at 100	60	69	69	66	73

* See Table XXVI for details of seeding.

† The excessive figure for Italian rye-grass is due to the presence of "rogue" plants derived from a previous sowing.

‡ No count of wild white clover was made in the second harvest year.

and this notwithstanding the fact that cocksfoot is itself dominated by the rye-grasses. Under extreme competitive conditions, especially during the seeding year, Italian rye-grass does lower the establishment and depress the growth

of red clover. As a plant in hay, however, the late flowering strain of red clover often holds its own against the rye-grasses—indeed if maiden seeds containing both these species be grazed well into the late spring, red clover may often become aggressive and depress the growth of the rye-grasses in the hay crop.

Establishment data for the second harvest year (1927) given as part of Table XXIX show that the differences between the plots have to some measure been levelled out. The differences between first and second harvest year figures are greatest in mixture 1 sown without rye-grass, and conversely appear to be least in mixture 5 with excessive seedings of rye-grass ; a corresponding gradation is shown in the intermediate mixtures. In all mixtures containing rye-grass there have been increases in the number of plants of meadow fescue, timothy and meadow grass plants from 1926 to 1927, whereas in mixture 1 (without rye-grasses) the number of meadow fescue and timothy plants has decreased. For rough-stalked meadow grass all plots show an increase in numbers, but this may, or may not, be due to the appearance of indigenous unsown plants of this grass. It is, however, more likely, having regard to evidence obtained from a fairly extensive range of seeds mixture experiments, that delayed germination has played an important part, directly influencing the results for meadow grass. This view is supported by the fact that in 1926 the meadow grass showed a downward trend from mixture 1 to mixture 5—the comparative figures in 1927 show but slight, and at that irregular variation.

The data indicate that sward production from the sowing out of a seeds mixture is a function of plant establishment, followed on the one hand by more or less heavy casualties during the first 12 to 24 months after sowing, but on the other hand there remains a certain amount of dormant seeds which later may germinate and thereby tend to increase the plant population of the sward. The indications are that environmental factors, many of which are controllable by man, influence dormancy and delayed germination. Date of sowing and the intensity of competition are both factors which are shown to have considerable effect upon this phenomenon. It may be said that adverse conditions in general, whether climatic, agronomic or edaphic, tend to favour dormancy, and it is only with the advent of more genial growth conditions that seed that has remained latent will start to grow and exercise a marked influence on sward development.

(2) *Effect of Treatments upon Yields.*

(i) *Hay.*

(*a*) *Date of Sowing.*

The influence of sowing date upon the yield of hay is even more marked than upon establishment. Table XXX shows a striking reduction in the first harvest year hay yield from the August sowings, as compared to those given for the three sections (I—III) sown in the spring. The individual species, however, are not all affected in the same way. Perennial rye-grass, for example, shows relatively small decreases consequent upon late sowing, whereas meadow fescue, timothy, cocksfoot, and the clovers gave much lower yields when sown in August. Meadow fescue indeed has been almost a complete failure, giving only negligible yields on the August sown plots. Italian rye-grass on the other hand has yielded as well from August sowing as from the average spring sowings.

TABLE XXX.—*Showing* (1) *the yields as air-dried hay in cwt.* (= 100 *lb.*) *per acre in the first and second harvest years*; (2) *the influence of sowing date upon the sown species considered individually—four dates of sowing*: *E.* 62: *Lane Field.*

Year	1926 first harvest year.					1927 second harvest year.				
Reference number	I.	II.	III.	IV.	Average	I.	II.	III.	IV.	Average
Month of sowing 1925	March.	April.	May.	August.		March.	April.	May.	August.	
Perennial rye-grass	10.92	10.99	10.94	7.98	10.21	6.59	6.05	5.68	3.42	5.44
Italian rye-grass	7.59	14.97	10.51	10.47	10.89	2.75	4.37	2.95	0.77	2.71
Cocksfoot	2.61	2.84	2.64	0.85	2.24	4.38	3.83	2.45	1.56	3.06
Timothy	3.03	3.35	2.23	0.76	2.34	4.94	5.30	3.66	1.74	3.91
Meadow fescue	1.24	1.62	2.52	0.04	1.36	1.25	2.09	1.51	0.05	1.23
Meadow foxtail	0.08	0.11	0.12	..	0.08	0.08	0.07	0.04	..	0.05
Rough-stalked meadow grass	1.05	1.26	1.16	1.00	1.12	5.58	4.78	4.34	2.04	4.19
Late flowering red clover	34.99	28.87	32.62	5.98	25.62	3.04	3.07	2.40	5.71	3.56
Wild white clover	1.79	1.22	1.39	0.34	1.19	0.32	0.16	0.37	0.92	0.44
Weeds (= unsown plants)	3.72	2.08	2.20	4.22	3.07	1.80	0.83	1.02	2.13	1.45
Total	67.02	67.31	66.33	31.64	..	30.73	30.55	24.42	18.34	..
Relative	100	100	99	46	..	100	99	80	60	..

The teaching of these results is that March sowing appears to be on the early side for maximum yields in most grasses. Meadow fescue and rough-stalked meadow grass appear to be especially responsive to good sowing conditions, giving their highest yields after a May sowing. There are indications that meadow foxtail behaves in the same way, but the figures for this species are too low in the present experiment to have real significance.

The clovers appear to be less affected than the grasses by sowing date within the spring period, but are especially responsive to spring as opposed to autumn sowing.

The average yields in the second harvest year (1927) were considerably lower than in the first harvest year, but this has been due in large part to the lower productivity of rye-grass and red clover. Cocksfoot, timothy, and rough-stalked meadow grass have, on the average, given higher yields in the second, than in the first harvest year. This is largely attributable to the reduced competition from the rye-grass and red clover in the second year.

TABLE XXXI.—*Showing* (1) *the yields as air-dried hay in cwt.* (= 100 *lb.*) *per acre in the first and second harvest years*; (2) *the influence of nurse crop upon the several sown species*: *E.* 62 I—III: *Lane Field.*

Year	1926 1st harvest year.			1927 2nd harvest year.		
Reference	A.	B.	C.	A.	B.	C.
"Nurse" crop	Ripe oats.	Fodder oats.	No nurse.	Ripe oats.	Fodder oats.	No nurse.
Perennial rye-grass	10.47	10.77	11.94	6.49	6.00	5.81
Italian rye-grass	11.49	10.32	11.26	3.31	3.29	3.46
Cocksfoot	2.23	2.75	3.07	3.66	3.29	3.72
Timothy	2.53	2.98	3.18	4.08	4.82	5.02
Meadow fescue	1.47	1.42	2.50	1.54	1.33	1.77
Meadow foxtail	0.11	0.15	0.10	0.03	0.05	0.12
Rough-stalked meadow grass	1.10	1.19	1.18	4.59	5.50	4.99
Late flowering red clover	31.56	32.78	34.84	2.80	2.86	2.85
Wild white clover	1.60	1.48	1.35	0.29	0.30	0.27
Weeds (= unsown plants)	2.70	2.74	2.56	1.39	1.32	1.20
Total	65.26	66.58	71.98	28.18	28.76	29.21
Relative, ripe oats 100	100	102	110	100	102	104

(*b*) *Effect of the Nurse Crop.*

Table XXXI shows the hay yields grouped to compare the influence of the three systems of "nurse": the poor stand of oats has already been referred to. The results, however, show that even a thin nurse crop will suffice to reduce hay yields in the first and even in the second harvest year. Smaller yields for both grasses and clovers in the first year are general in methods "A" and "B" as compared to the "no nurse" series (= "C"). This evidence is not so clearly marked in the second harvest year when the yields have more or less levelled up, yet it is instructive to realize that the effect of a nurse crop, thin as this certainly was in the present experiment, can be traced even into the second harvest year.

TABLE XXXII.—*Showing the yields as air-dried hay in cwt. (= 100 lb.) per acre in the first and second harvest years; the influence of perennial and Italian rye-grass upon the yield of the several sown species: E. 62 I—IV: Lane Field.*

Year	1926 first harvest year.				
Number of mixture	(1)	(2)	(3)	(4)	(5)
Rye-grass seeding in lb. per acre	..	10	12	16	28
Perennial rye-grass	..	16.35	10.57	9.62	6.40
Italian rye-grass	..	..	5.59	11.49	15.80
Cocksfoot	5.85	2.60	2.03	1.42	0.61
Timothy	6.46	2.46	2.18	1.51	0.86
Meadow fescue	5.05	1.28	0.72	0.55	0.36
Meadow foxtail	0.11	0.10	0.11	0.06	0.09
Rough-stalked meadow grass	2.31	1.37	0.93	0.55	0.45
Late flowering red clover	30.08	32.58	31.62	28.82	29.98
Wild white clover	1.58	1.45	1.19	1.36	1.31
Weeds (= unsown plants)	5.95	3.38	1.65	1.75	1.29
Total	57.39	61.57	56.59	57.13	57.15
Relative	100	107	99	100	100
Total without perennial and Italian rye-grass	57.39	45.22	40.43	36.02	34.95
Relative	100	79	71	63	61
	1927 second harvest year.				
Perennial rye-grass	..	6.98	6.58	5.66	5.22
Italian rye-grass	..	..	1.53	2.63	5.90
Cocksfoot	4.85	4.07	3.98	2.86	2.02
Timothy	7.06	5.66	4.26	3.52	2.70
Meadow fescue	4.30	1.84	0.85	0.54	0.22
Meadow foxtail	0.07	0.09	0.08	0.06	0.03
Rough-stalked meadow grass	4.70	5.35	5.69	4.72	4.68
Late flowering red clover	1.92	2.74	2.66	3.14	3.69
Wild white clover	0.31	0.33	0.34	0.24	0.22
Weeds (= unsown plants)	2.90	1.10	0.80	0.69	0.60
Total	26.11	28.16	26.77	24.06	25.28
Relative	100	108	102	92	97
Total without perennial and Italian rye-grass	26.11	21.18	18.66	15.77	14.16
Relative	100	81	72	60	54

(c) *Influence of Rye-grasses upon Yields.*

Data are given in Table XXXII to show the effect of additional seedings of rye-grasses upon the hay yield of the other constituent species, as well as upon the gross weight of hay. The aggressive nature of the rye-grasses is clearly evident from the figures. The yields of cocksfoot, timothy, and meadow fescue are reduced to small relative proportions by excessive seedings of Italian rye-grass. In species where the reduction in yield is due primarily to a decrease in soil establishment as, for example, in the case of meadow fescue, the second year yields show wide variations from mixture 1 (no rye-grass) to mixture 5 (28 lb. rye-grass) comparable in every way to the first year figures. In cocksfoot on the other hand, where the lower yield is due to suppression of growth and loss in vigour rather than to decreased establishment, the yield shows a decided recovery in the second hay crop, during the growth period of which competition with Italian rye-grass has been largely removed. There is, therefore, levelling up of yields in cocksfoot, timothy, rough-stalked meadow grass, and perennial rye-grass in the second year hay, but the aggregate yields still show equally wide variations as indicated by the average relative figures given in Table XXXII. The data have clearly shown that the rye-grasses set up an intense competition under certain conditions and that although they may not completely dominate the herbage yet they entirely change its botanical composition, not only in the first, but also in subsequent harvest years.

The rye-grasses being comparatively short-lived* and of outstanding aggressiveness in hay are capable of doing considerable harm, since they tend to speed up sward spoliation. Having regard, however, to their rapid development from seed and also to their capacity for quick recovery after cutting, the rye-grasses can be valuable constituents of a correctly managed newly sown ley. There is considerable evidence to show that Italian rye-grass is an excellent pasture plant and as such is an invaluable asset to the general grassland economy of the farm. The results from the present, among other experiments at the Station, indicate that it is a misinformed practice to regard the rye-grasses primarily as hay plants. Their production of leaf in hay is generally low, whilst they are not of outstanding productivity—not comparing favourably, for example, with the better strains of late red clover or even with many of the more persistent of the larger grasses. As pasture plants, on the other hand, they are capable of a high yield of leafy herbage and make quick recovery after defoliation.

(ii) *Aftermath.*

The yields and botanical composition of the aftermath were ascertained in the first year but only for the "no nurse" plots (method C). Comparisons are therefore made in respect of sowing date and of the different mixtures with their contrasting seed rates of the rye-grasses. The data given in Table XXXIII permit of the following general conclusions being drawn :—

The sowing date has not influenced the aftermath yields of the first harvest year to so great an extent as the hay yields of that year. There has been some levelling up of yields from the different sowing dates and this appears to be especially true in the case of red clover, white clover, and cocksfoot. Obser-

* Indigenous stocks of perennial rye-grass now being built up at the Station are more persistent than ordinary commercial stocks, but are in general pre-eminently suitable for use as pasture, as opposed to hay.

vations made on the plots corroborate the statistical evidence. Emphasis is laid upon the distinct increase in percentage of red clover on the August sown plots in aftermath as compared to hay.

TABLE XXXIII.—*Showing the yields of aftermath in cwt.* (= 100 *lb.*) *per acre for the first harvest year* 1926; *the effect of* (1) *date of sowing*; *and* (2) *additional rye-grass seedings upon yields in the several sown species* (*no nurse crop—method C*): *E.* 62 I—IV: *Lane Field.*

Reference number	I.	II.	III.	IV.	Average
Month of sowing, 1925	March.	April.	May.	August.	
(1) *Influence of date of sowing.*					
Perennial rye-grass	3.23	3.12	3.07	2.40	2.96
Italian rye-grass	3.46	4.66	3.25	1.41	3.20
Cocksfoot	7.05	8.10	6.10	4.35	6.40
Timothy	1.00	0.71	0.82	0.34	0.72
Meadow fescue	2.26	2.10	2.25	0.16	1.69
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	0.36	0.28	0.15	0.49	0.32
Late flowering red clover	18.40	18.10	15.00	11.85	15.84
Wild white clover	0.19	0.28	0.30	0.96	0.43
Total	35.95	37.35	30.94	21.96	..
Relative	100	104	84	61	

Number of mixture	1	2	3	4	5
Rye-grass seeding in lb. per acre	..	10	12	16	28
(2) *Influence of rye-grass.*					
Perennial rye-grass	..	1.55	2.28	3.64	4.90
Italian rye-grass	..	..	1.86	2.88	4.85
Cocksfoot	10.65	8.40	7.00	3.00	2.32
Timothy	0.89	0.70	0.77	0.70	0.37
Meadow fescue	3.54	1.71	0.61	0.38	0.44
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	0.09	0.44	0.13	0.48	0.30
Late flowering red clover	11.90	16.40	14.15	18.40	15.30
Wild white clover	0.49	0.57	0.25	0.61	0.70
Total	27.56	29.77	27.05	30.09	29.18
Relative	100	108	95	109	106
Total without perennial and Italian rye-grass	27.56	28.22	22.91	23.57	19.43
Relative	100	102	83	86	70

* Weights negligible.

TABLE XXXIV.—*Showing the average hay yield in milligrammes of air-dried fodder per plant: the influence of sowing date upon vigour in the several sown species: first and second harvest years hay: E. 62 I—IV: Lane Field.*

Year	1926 first harvest year.					1927 second harvest year.				
Reference number	I.	II.	III.	IV.	Average	I.	II.	III.	IV.*	Average
Month of sowing	March.	April.	May.	August.		March.	April.	May.	August.	
Perennial rye-grass	765	501	487	339	518	979	803	648	296	682
Italian rye-grass	461	625	554	545	546	537	518	457	171	421
Cocksfoot	135	127	139	36	109	318	287	203	109	229
Timothy	413	393	350	215	343	783	590	408	222	501
Meadow fescue	276	310	538	27	288	357	457	293	16	281
Meadow foxtail†	..	..	..	..	..	..	..	..	..	..
Rough-stalked meadow grass	122	193	155	148	155	342	297	318	143	275
Late flowering red clover	3,450	2,380	3,180	2,280	2,823	1,840	1,025	780	3,230	1,719
Wild white clover	297	167	191	69	181	..	..	..	..	..
Average without meadow foxtail and wild white clover	775	647	772	513	..	737	582	444	598	..

* Part IV was cut on July 13th, 1927, the main body of the experiment having been cut on June 16th (27 days earlier).
† Weights negligible.

The data already referred to in Table XXX with reference to second year yields of hay are corroborated in every detail by the data in Table XXXIII ; the results show, therefore, experimental reliability. The higher relative yield of red clover in the aftermath, as opposed to hay, is attributable to an increased vigour per plant, due to greatly decreased competition on the August sown plots as compared to those sown in spring.

In view of the fact that establishment was poor from the August sowing, the number of plants per unit of area was relatively small, and, therefore, throughout the first year competition was at a minimum. The constituent plants had not made sufficient growth within the restricted period to permit of their contributing heavily to the June hay crop of the first year, but had made better development by the September cut. The evidence is strongly in support of the thesis enunciated by Stapledon (21) based on evidence from the earlier garden trials, namely, that the " time-condition " factor exercises considerable influence upon the yield and other behaviour of species sown in seeds mixtures. A considerable proportion of the plants that had overwintered from the late sowing were evidently still in the seedling stage by the spring of the first harvest year (1926), and, therefore, were in many respects comparable to " plants " derived from sowings made early in the spring of that year (1926), with the important difference of showing in the aggregate a much lower percentage establishment

White clover has given its highest yield as aftermath from the August sowing, and this fact furnishes further evidence to show that competition was by that much the less on the "August " than on the " spring " plots.

The average yields of aftermath in the first harvest year given by the five mixtures with their contrasting seed rates of rye-grass bear to one another a relation similar to that found in the hay crop. It is important to note, however, that cocksfoot is a much heavier contributor to the aftermath than to the hay. Moreover, as a result of the preponderantly leafy aftermath given by cocksfoot, this grass is more highly aggressive at the end of the year than during the hay period. Table XXXIII (2) shows that red clover, for example, has given considerably higher aftermath yields in the " with rye-grass " mixtures than in the " no rye-grass " mixture, where cocksfoot was predominant. The yield of late red clover in the several mixtures is inversely proportional to the aggregate yields of the rye-grasses and cocksfoot, indicating that in the aftermath cocksfoot is at least as aggressive towards red clover as are the rye-grasses.

(3) *Vigour of Plant Growth in Hay and Aftermath.*

In the present instance vigour has been estimated by calculating the average yield per plant (dry fodder) in both hay and aftermath. The gross yield of any particular species as well as the average number of plants per unit of area were ascertained, and it was, therefore, a matter of calculation to find the average plant weights : these are in all cases given in terms of milligrammes of air-dried fodder per plant. Vigour has further been investigated in cocksfoot by making measurements of height of flower stems.

(*a*) *Influence of Sowing Date on Vigour.*

The average weights per plant as hay are given for each sown species in Table XXXIV, the influence of sowing date upon plant vigour being shown for both first and second harvest years. Spring sowings in general give better

developed and larger plants than autumn sowings. This is most marked in meadow fescue and cocksfoot, whilst timothy, red clover, white clover, and perennial rye-grass show equally definite, even if less marked, response. Italian rye-grass has given, on the average, larger plants from the August than from the March sowing—its capacity for good establishment and high productiveness over a long range of sowing dates has already been indicated. The large size of the plants from a late sowing must, however, be connected to a considerable extent with less competition from other species, especially red clover and cocksfoot.

The aftermath data (first harvest year only) are shown in Table XXXVII, p. 128, and these in the main confirm the hay data. Plants from the August sowings are less productive in aftermath than those derived from spring sowings, and in this case the two rye-grasses conform to the general rule. Late red clover, however, has been much more productive on the "per plant" basis from an August sowing. This is entirely borne out by notes made on the plots before cutting the aftermath, and is due not only to the less keen sward competition on these plots, but also to the effects of delayed development in red clover consequent upon the late sowing. Rough-stalked meadow grass and wild white clover also give plants of higher productivity in aftermath on the August sown plots. Comparing the hay and aftermath in respect of plant vigour, emphasis is to be laid on the fact that aggressiveness as such is not confined to any one species, or to any particular growth period, and in consequence a species which is non-aggressive in June-hay may be the aggressor species in the aftermath. Cocksfoot, for example, owing to increased productivity per plant has given three times as large a yield of aftermath as of hay. Moreover, whereas in commercial cocksfoot the hay is inclined to be stemmy the aftermath is wholly leaf, and is thereby so much the more an aggressive component of the herbage. In the second harvest year the yield per plant has not fallen to

TABLE XXXV.—*Showing the average hay yield per plant in milligrammes of air-dried fodder; the influence of "nurse" crop upon vigour in the first and second harvest years hay. E. 62 I—III: Lane Field.*

Year	1926 1st harvest year.			1927 2nd harvest year.		
Reference	A.	B.	C.	A.	B.	C.
"Nurse" crop	Ripe oats.	Fodder oats.	No nurse.	Ripe oats.	Fodder oats.	No nurse.
Perennial rye-grass	489	572	619	807	813	668
Italian rye-grass	603	529	564	408	612	406
Cocksfoot	103	143	150	269	230	266
Timothy	345	421	453	496	608	626
Meadow fescue	382	346	478	417	296	380
Meadow foxtail*	..	..	..	..	..	..
Rough-stalked meadow grass	132	163	191	250	358	327
Late flowering red clover	2,980	3,160	3,740	1,120	1,125	2,120
Wild white clover	219	229	216	..	..	..
Average without meadow foxtail and wild white clover	719	762	885	538	577	685

* Weights negligible.

any appreciable extent except in spring sown red clover. Average plant yields in most cases have increased in comparison with the first year figures and especially in timothy, cocksfoot, and meadow grass, all of which were badly handicapped by the competitive influence of rye-grass and of red clover during the growth of the first hay crop. The very high figure for vigour in red clover (Part IV, 1927) is largely, if not absolutely, due to these plots being cut at a later date than the main body of the experiment: this fact of course applies to all species, but is especially pronounced in red clover.*

(*b*) *Influence of Method of Sowing on Vigour.*

Data given in Table XXXV show the comparative effect of the three methods of "nurse" (A to C) upon yield per plant in the sown species. Poor as the nurse crop proved to be, the results clearly show that it has caused a reduction in vigour during the first harvest year. On the average the most vigorous plants were produced when not subjected to the influence of a nurse (method C), whilst plots under ripe nurse (method A) gave the smallest plants. The indications therefore are that although establishment may not be affected to any important extent by a thin nurse crop, nevertheless average yields may be affected quite appreciably. A normal crop of oats would have had a proportionately greater effect upon gross yields and upon vigour. These results demonstrate that a nurse crop has a depressant action upon gross yield and vigour of herbage plants in the first hay crop. For most species these differences are minimised in the second hay crop, but in the case of late red clover the individual plants were twice as productive on the "no nurse" section (C) as elsewhere.

(*c*) *Influence of the Rye-grasses on Vigour.*

Table XXXVI shows very clearly that the rye-grasses are sufficiently aggressive to cause a reduction in yield per plant of other grasses and clovers. The reduction in vigour appears to be general for all the species and is directly proportional to the additional seedings of rye-grass. Perennial rye-grass is shown to be aggressive in competition with cocksfoot, timothy, and meadow fescue, whilst excessive seedings of Italian rye-grass cause further reduction in all species including perennial rye-grass itself. The figure for meadow fescue (mixture 5—Table XXXVI) is irregular, and, whilst being confirmed by the aftermath results (Table XXXVII), is not corroborated by the data for second year hay. In the latter case differences in yield per plant are not so striking as in the first hay crop, but there can be no doubt that the effect of keen competition during the early period is carried on into subsequent years. This is strongly indicated, for example, by the figures for cocksfoot and meadow fescue in mixtures 1 to 5 (Table XXXVI—1927). In the second harvest year perennial rye-grass has probably a greater competitive effect than Italian rye-grass, while there is every indication that cocksfoot has an important influence upon species making contemporary growth with it. The data given in Table XXXVII appear to show that plants in mixture 1 where cocksfoot was dominant in the aftermath, were, on the whole, less vigorous (aftermath) than in mixtures containing rye-grass where cocksfoot had been considerably checked. There

* Hay from five plots of the August sown series was cut in the second harvest year 27 days later than the main body of the experiment. This course was adopted for the convenience of farmers' parties visiting the Station.

TABLE XXXVI.—*Showing the average hay yield per plant in milligrammes of air-dried fodder; the influence of additional rye-grass seedings upon vigour in the first and second harvest years hay: E. 62 I—IV: Lane Field.*

Year	1926 first harvest year.				
Number of mixture	(1)	(2)	(3)	(4)	(5)
Rye-grass seeding in lb. per acre	..	10	12	16	28
Perennial rye-grass	..	570	579	547	420
Italian rye-grass	..	..	501	670	510
Cocksfoot	218	109	100	89	43
Timothy	540	337	319	298	334
Meadow fescue	510	374	253	217	550
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	221	178	162	81	65
Late flowering red clover	3,190	3,100	3,290	2,690	2,600
Wild white clover	197	227	195	207	202
Average without meadow foxtail and wild white clover	936	778	743	656	646
	1927 second harvest year.				
Perennial rye-grass	..	825	770	755	833
Italian rye-grass	..	..	398	482	581
Cocksfoot	341	282	296	236	185
Timothy	618	650	630	470	632
Meadow fescue	565	423	254	207	110
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	277	341	371	263	294
Late flowering red clover	1,250	1,015	988	1,315	1,030
Wild white clover*	..	..	..	..	..
Average without meadow foxtail and wild white clover	610	589	530	533	524

* Weights negligible.

are further indications to show that the rye-grasses are not serious competitors in aftermath. In view of the comparatively low yield of perennial rye-grass at this period and of the open growth-form of Italian rye-grass, it is not to be expected that these plants can suppress more actively growing and vigorous species. The teaching of these data, therefore, seems to be that aggressiveness may pass from one species to another not only from year to year but from early to late season. All the evidence so far discussed shows that Italian rye-grass is most aggressive in swards during the seeding year and up to about the end of May or early June of the first harvest year. Perennial rye-grass can, however, be an aggressor in the second or even third hay crop; under hay conditions other grasses such as cocksfoot or tall oat grass may assume aggressiveness during the later harvest years, or if sown without rye-grass may dominate swards in the first year. In the first hay crop, the late strains of red clover with their leafy canopy of herbage have shown true aggressiveness in many instances. The better of these strains may also be aggressors in the first and second year aftermath.

TABLE XXXVII.—*Showing the average yield per plant in milligrammes of air-dried fodder; the influence of* (1) *date of sowing; and* (2) *additional seedings of rye-grass upon plant vigour in the aftermath of the first harvest year* 1926 (*method C*): *E.* 62 I—IV: *Lane Field.*

Reference number	I.	II.	III.	IV.	Average.
Month of sowing, 1925	March.	April.	May.	August.	
(1) *Influence of date of sowing.*					
Perennial rye-grass	226	142	137	102	152
Italian rye-grass	214	195	171	74	164
Cocksfoot	365	364	321	185	309
Timothy	134	83	128	96	110
Meadow fescue	502	402	500	109	378
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	42	43	20	72	44
Late flowering red clover	1,815	1,490	1,460	4,608	2,343
Wild white clover	32	37	41	195	76
Average without meadow foxtail and late red clover	216	181	188	119	

Number of mixture	(1)	(2)	(3)	(4)	(5)
Rye-grass seeding in lb. per acre	..	10	12	16	28
(2) *Influence of rye-grass.*					
Perennial rye-grass	..	57	125	206	322
Italian rye-grass	..	..	166	166	147
Cocksfoot	397	354	344	187	165
Timothy	74	96	121	137	143
Meadow fescue	358	520	215	149	673
Meadow foxtail*	..	..	..	..	..
Rough-stalked meadow grass	10	57	23	71	44
Late flowering red clover	1,240	1,550	1,470	1,720	1,330
Wild white clover	61	89	41	93	106
Average without meadow foxtail and the rye-grasses	357	444	369	370	410

* Weights negligible.

Measurements taken on the flowering stems of cocksfoot have been summarized in Table XXXVIII. Two series of readings were taken, one to ligule of the uppermost leaf of the stem (= flag leaf) and the second to apex of panicle. The results are the average of ten readings per plot on a large number of plots.

The influence of competition as exampled by the effect of rye-grass in the first year hay is further demonstrated by these figures. The difference in value between the two readings gives an index of the proportionate length of inflorescence—this difference becomes less as the seeding of rye-grass, and therefore the extent of competition in hay, is increased. Not only so, but the vigour of

TABLE XXXVIII.—*Showing the average height in cms. to the apex of inflorescence and to ligule of flag leaf (= uppermost stem leaf) in cocksfoot: influence of additional rye-grass seedings upon vigour as measured by length of flowering parts: Hay—first harvest year* 1926: *E.* 62 I—IV: *Lane Field.*

Number of mixture	(1)	(2)	(3)	(4)	(5)
Seeding of rye-grass in lb. per acre	..	10	12	16	28
Height to apex of panicle	95	83	81	80	79
Height to ligule of flag leaf ..	68	60	59	58	57
Difference	27	23	22	22	22

flowering as measured by the total height of flowering stems in cocksfoot is also decreased by intense competition. Other experiments at the Station have shown that competition causes a decrease in total numbers of inflorescences in many grass species. These data have, therefore, an important bearing upon the relation of competition in its several aspects to the general economy of grass and clover seed production. The implication is that after a certain point increased seed rates may do much harm in relation to production of seed, whilst, on the other hand, for pasture purposes thick sowings may be calculated to produce denser swards and a more leafy herbage.

E. 62: Summary to the Experiment.

(1) Spring sowing may be expected under conditions of high rainfall to give better results than sowings made in August—results which show themselves even more strongly in the hay yields in the first harvest year than in 'establishment.'

(2) A cereal nurse crop tends to handicap the development of newly sown "seeds" and has a depressant effect upon the establishment and yield of young leys.

(3) The rye-grasses compete against and adversely affect other herbage plants commonly employed in seeds mixtures. Establishment, yield, and vigour may be markedly reduced by excessive seedings of the rye-grasses and especially if the latter are allowed to grow away unchecked.

(4) The phenomenon of delayed germination of sown seeds has again been demonstrated; latency seems to be increased by excessive competition, by sowing late in the season, and by adverse conditions generally.

E. 72: SEEDS MIXTURE EXPERIMENT TO TEST THE INFLUENCE OF DATE OF ENCLOSURE TO HAY UPON THE ESTABLISHMENT AND YIELD OF HERBAGE PLANTS: GORSE FIELD. SOWN 1926.

This experiment deals with the influence of the date of "putting up" upon the yield and botanical composition of first year "seeds" hay. The

effect of late spring grazing has been critically investigated with special reference to the rôle and usage of Italian rye-grass in the seeds mixture. The experiment is the outcome of the preliminary investigations dealing with the effect of date of enclosing fields upon both crop and resultant sward : this report is therefore a sequel to a previous report by Stapledon and Davies (19).

MATERIAL AND METHODS.

The trial was conducted on the Gorse Field, the soil being light and stony. The area, which had been down to grass for many years, was ploughed up to oats in 1924. Roots were grown in 1925, when a dressing of farmyard manure at the rate of 10 tons per acre in addition to 5 cwt. per acre of basic slag was applied. The ground was re-ploughed for seeds which were sown on May 6th, 1926, without a nurse crop. Twelve different seeds mixtures were used : each had a common base of 6 grasses and clovers, but differed in the seeding of cocksfoot and meadow fescue : there were, furthermore, contrasting seed rates of Italian rye-grass. Table XXXIX gives details of the seeds mixtures—123 1/400th acre plots were sown on a basis of from 10 to 12 replications for each seeds mixture employed.

TABLE XXXIX.—*Showing the seeds mixtures sown in lb. per acre (at real value = 100) : E. 72 : sown May 6th, 1926 : Gorse Field.*

Species.	Number of mixture.											
	1	2	3	4	5	6	7	8	9	10	11	12
Italian rye-grass	..	4	10	16	..	4	10	16	..	4	10	16
Cocksfoot (commercial)	10	10	10	10	..	..	..	..	..	..	..	..
Cocksfoot (indigenous)	..	..	..	..	10	10	10	10	..	..	..	..
Meadow fescue	..	..	..	..	..	..	..	..	10	10	10	10
Timothy	4	4	4	4	4	4	4	4	4	4	4	4
Crested dogstail	2	2	2	2	2	2	2	2	2	2	2	2
Tall oat grass	4	4	4	4	4	4	4	4	4	4	4	4
Rough-stalked meadow grass ..	2	2	2	2	2	2	2	2	2	2	2	2
Montgomery red clover	4	4	4	4	4	4	4	4	4	4	4	4
Wild white clover	2	2	2	2	2	2	2	2	2	2	2	2

The experiment was in four parts, each part being enclosed for the 1927 hay crop on the following dates :—

Part I. October 8th, 1926.
,, II. February 15th, 1927.
,, III. April 21st, 1927.
,, IV. May 13th, 1927.

The whole experiment was run over with the mowing machine in July, 1926 (seeding year) ; the produce containing considerable quantities of arable land weeds was raked off the plots immediately after cutting. The plots were again cut on October 8th, 1926, this crop being weighed and samples taken for both dry weight and botanical estimation in accordance with the technique of fodder analysis adopted at the Station (see Davies (4)).

Part I of the experiment was then " put up " to hay. From January until May the remaining parts (II—IV) were grazed on an intermittent basis by sheep

and in sympathy with the several dates of " putting up " to hay as given in the statement above. Quantitative samples were taken on representative plots previous and subsequent to each grazing period, so that the weight of grass eaten by the sheep could be estimated. These samples were, moreover, analysed botanically, and consequently the relative proportion of each species consumed by the sheep was determined. All the plots were cut for hay on July 13th, 1927, a date at which the first enclosed plots (part I) were overmature, while, at the other extreme, part IV carried a young "herby" hay with a high proportion of clover. In 1927, the months of May and early June were very dry, while the rainfall during the latter half of June and throughout July was abnormally high—weather conditions not conducive to early mowing. The lateness of cutting probably favoured the yield of plots " put up " in May as compared to the yield from those enclosed at an earlier date. Conversely, however, the low rainfall experienced in May itself is likely to have handicapped recovery after grazing, therefore adversely affecting the yield from part IV of the experiment. The hay from each plot was weighed on cutting, samples being taken for botanical analyses* and for dry weight estimations. In August, 1927, ten turfs (6 inches by 6 inches) were lifted from each plot, and counts of plants occurring within this area were made in the field laboratory. It has, therefore, been possible to ascertain (1) the actual weight of hay contributed by each species ; (2) the average yield per plant ; (3) the vigour of flower production ; and (4) the yield respectively of "stem" and of "leaf" : each of the above factors having been under investigation for different types of management reacting on different and contrasting seeds mixtures.

Discussion of Results.

(1) *Effect of Date of " Putting up " to Hay.*

(*a*) *Yields in the first harvest year.*

Table XL shows the average hay yields of each species in cwt (= 100 lb.) per acre when " put up " to hay at the four contrasting dates. Their behaviour is noteworthy : Italian rye-grass and tall oat grass, both making early spring growth, gave their highest yields in part I (enclosed in October of the seeding year). Species that make medium early growth, represented by cocksfoot and meadow fescue, have given their highest yields in part II (grazed up to February), whereas plants not normally starting spring growth until April is well advanced, and represented here by timothy, crested dogstail, the meadow grass, and clovers, have each attained the maximum in part III (grazed until April 21st). All species had begun active growth by the middle of May, and therefore both individually and in the aggregate the species have given a decreased yield as a result of the late date of enclosure. We have therefore the seeming anomaly that spring grazing increases the yield of clover and of the late spring grasses ; this is consequent upon the weakening of the highly aggressive Italian rye-grass which therefore allows of a better development of species which are potentially heavy contributors to the hay, but which are handicapped by unhampered competition from this vigorous early grass. The aggregate yields of Montgomery red clover and of wild white clover are themselves interesting in this

* These samples were subjected to the following analyses :—

(*a*) Into species by percentage estimation (productivity).
(*b*) " Stem and leaf."
(*c*) Counts of total number of panicles in the grasses.

TABLE XL.—*Showing the air-dried yields in cwt. (= 100 lb.) per acre of a number of herbage plants sown in seeds mixtures and "put up" to hay at four contrasting dates. Hay—first harvest year 1927: E. 72 I—IV: Gorse Field.*

Reference number	I.	II.	III.	IV.
Date of "putting up" to hay (1926—27)	October.	February.	April.	May.
Italian rye-grass	27.41	20.36	11.51	9.62
Tall oat grass	5.50	4.31	2.91	0.55
Cocksfoot (indigenous and commercial)	4.48	4.25	3.04	2.27
Meadow fescue	4.19	5.04	4.63	2.68
Timothy	2.61	4.04	3.48	2.52
Crested dogstail	3.78	3.94	4.73	3.10
Rough-stalked meadow grass	0.71	0.52	0.89	0.43
Montgomery red clover	12.20	15.91	20.75	16.11
Wild white clover	trace.	0.16	0.23	0.20
Weeds (= unsown plants)	0.89	1.24	1.81	1.37
Total Italian rye-grass and tall oat grass (early grasses)	32.91 (100)*	24.67 (75)*	14.42 (44)*	10.17 (31)*
Total cocksfoot and meadow fescue (medium early grasses)	8.67 (100)*	9.29 (107)*	7.67 (83)*	4.95 (57)*
Total other grasses (lates)	7.10 (100)*	8.50 (120)*	9.10 (128)*	6.05 (86)*
Total clovers (lates)	12.20 (100)*	16.07 (132)*	20.98 (172)*	16.31 (134)*

* Relative, with October "put up" at 100.

respect. They show very clearly the effect upon clover yields of late spring grazing and the value of utilising the Italian rye-grass as a spring grazing plant and not as a hay plant. The clover yields in part III of the experiment (grazed up to April 21st) are 172 per cent. of those given in part I (no spring grazing).

The yields produced under the contrasting dates of "putting up" are therefore a function of two master factors influencing productivity in opposite directions: *firstly*, the general tendency as shown by Stapledon (15, 17) for the yield in every species to be lowered by grazing in the spring, this being most marked in species that start growth earliest in the spring (Italian rye-grass and tall oat grass); *secondly*, in species which do not make growth until later in the season the decrease in yield is masked by an increase, consequent upon the removal of competition when the Italian rye-grass is grazed. In fact, when mixed pasturage containing quantities of Italian rye-grass is grazed on an intermittent basis during the spring months, stock give preference to the highly palatable and easily accessible rye-grass. It is, therefore, possible so to adjust the management that the stock are taken off before the late growing constituents are eaten to any appreciable extent. In this way Italian rye-grass, which is essentially a pasture plant attaining its greatest relative value in the spring,

TABLE XLI.—*Showing the total weight of pasturage and of Italian rye-grass consumed by sheep during the spring of the first harvest year (cwt. = 100 lb.): E. 72 I—IV: sown 1926.* *Gorse Field.*

Reference no. to expt.	Date of "putting up" to hay.	No. of spring grazing periods.	Air-dried weights per acre of spring pasturage actually consumed.		Spring grazing Italian rye-grass as a percentage of total amount consumed.
			Total cwt. (= 100 lb.)	Italian rye-grass cwt. (= 100 lb.)	
E. 72 I. ..	Oct. 8th, 1926	Nil.	..	..	..
E. 72 II.	Feb. 15th, 1927	2	4.10	2.04	49.8
E. 72 III. ..	Apr. 21st, 1927	4	6.10	3.28	53.5
E. 72 IV. ..	May 13th, 1927	5	8.22	4.30	52.3

is correctly utilised, and under these conditions it will not materially hamper the development of other species contributing to the hay crop.

(*b*) *Spring grazing.*

Table XLI shows the average air-dried weights (in cwt. per acre) of pasturage consumed on the plots by sheep during the spring of 1927. The amount of Italian rye-grass grazed is also given and is shown as 4.30 cwt. (period October—May) of air-dried matter or over 50 per cent. of the total consumption. These data give unmistakable evidence of the high value of Italian rye-grass as a spring grazing plant. It is of further interest to note that temporary grass on the poor stony bank on which the trial was situated has, during the October—May period, produced over 8 cwt. of dry grass per acre, 6.10 cwt. of which were fed off by mid-April, whereas first-rate old swards in the district have been calculated to produce no more than 5.81 cwt. per acre of air-dried fodder for a similar period.*

(*c*) *Leafiness of the Hay Crop.*

Late spring grazing makes for younger and more nutritious hay crops with a higher percentage of leafy material than those "put up" to hay early in the season. The following statement shows the average percentage of leaf (= leaf laminae) from the plots enclosed to hay at the four contrasting dates:—

Date of "putting up" to hay ..	October.	February.	April.	May.
Percentage leaf in the hay ..	19.0	22.1	23.4	29.3

The younger hay is not only more leafy, but the leaves and stems are in a less mature and therefore in a more nutritious stage. To ascertain the percentage leafage does not of course show the full relative value as between

* Data obtained in connection with trials (E. 79) now in progress (Nantsiriol—period October 3rd, 1927, to April 30th, 1928).

the contrasting series—although as is evident from the published reports from the Station the leaf-stem ratio affords an excellent rough measure of the nutritive value of a fodder. The stem in particular of the late enclosed hay has a considerably higher food value than stem in hay enclosed in October or even February.

(d) The Fodder Unit "Value" as Affected by Date of "Putting up" to Hay.

Throughout the investigations it has been evident that the total cash value of fodder lifted from the areas "put up" to hay at different dates has varied to a marked degree. It has been indicated that the hay crop was more leafy and thereby so much the more nutritious consequent upon the late date of enclosing to hay: the high relative value of spring grazing has also been indicated.

An attempt will now be made to assess the value of the produce given by these contrasting series of plots. The figures are at present strictly tentative, but seem to be worthy of publication in that they emphasize the value of carefully adjusting the spring grazing on temporary swards coupled with the harvesting of a light but nevertheless highly nutritious hay crop.

Unit marks were allotted on a scale as hereunder for the total yields obtained on the plots during the complete year July, 1926 (when the first seeding year cut was made) to July, 1927, when the first year hay crop was taken.

		Growth period.
1.00	marks per lb. of air-dried fodder cut on Oct. 8th, 1926.	July to Oct., 1926.
3.00	" " " " " grazed Jan. to May, 1927.	Oct., 1926 to May, 1927.
1.00	" " " " hay cut July 13th, 1927 (Pt. I)	Oct., 1926 to July, 1927.
1.16	" " " " " " " (Pt. II)	Feb. to July, 1927.
1.23	" " " " " " " (Pt. III)	April to July, 1927.
1.54	" " " " " " " (Pt. IV)	May to July, 1927.

The following observations will make more clear the basis for allocation of the marks:—

(*i*) The seeding year cut and the hay *ex* October "putting up" (part I) have throughout been placed at unity per lb. of air-dried fodder. Hay at the other dates of enclosure has been adjusted on the basis of percentage leaf in the hays, as, for example, *part I hay* contained 19.0 per cent. leaf (at unity) whereas *part I V hay* had 29.3 per cent. leaf, and was therefore considered to be $\frac{293}{190}$ =154 per cent. as valuable as the former. This system of allocation does not give true nutritive values, inasmuch as the hay crop as a whole was younger in part IV of the experiment, both stem and leafage therefore having a correspondingly higher food value per lb.

(*ii*) Fodder consumed during the spring months has been considered to have three times the cash value of summer feed on pasture. It is felt, however, that this tentative figure is a conservative one, and the indications are that when more data are available it may be proved that spring pasturage in Britain is from six to ten times as valuable commercially as summer or autumn grass.

Table XLII shows the number of "fodder units" per acre given by plots "put up" at different dates. These data indicate very definitely that allowing maiden seeds containing Italian rye-grass to be ungrazed during the spring months results in a not inconsiderable loss in food values. Not only is the spring keep forfeited, but there is naturally a loss in nutritive value of the hay as measured

TABLE XLII.—*Showing the number of "fodder units" per acre given by plots "put up" to hay at four contrasting dates: E. 72 I—IV: 1926—27: Gorse Field.*

Reference number	I.	II.	III.	IV.
Date of "putting up" to hay. ..	October 1926.	February 1927.	April 1927.	May 1927.
	Units.	*Units.*	*Units.*	*Units.*
Seeding year cut (October)	2,880	2,760	2,420	2,640
Spring grazing, 1927	..	1,230	1,830	2,466
Hay, 1927	4,924	5,780	5,800	5,240
Total	7,804	9,770	10,050	10,346
Relative with Part I at 100	100	125	129	133

by its percentage leaf. Grazing such a sward well into May and taking a young leafy hay crop from it will give the highest total value on the "fodder unit" basis. On the present calculations, "putting up" to hay in May has given a value at least 133 per cent. of that contributed by a similar series of plots "put up" in October of the seeding year.

(*e*) *Size of Plant* (= *Vigour*).

The number of plants per unit of area as well as the gross yields of each species having been ascertained, it was possible to calculate the average weight per plant in hay of the individual sown species. The relative yields of rough-stalked meadow grass and of wild white clover were, however, in general very low, and therefore have been omitted from the present calculations, as it was felt that in dealing with such small yields the experimental error was large and any figures would thereby lack significance. It is clear, however, from the yield data in Table XL that both these species were affected in exactly the same way as the other species dealt with.

TABLE XLIII.—*Showing the air-dried hay yield in milligrammes per plant in a number of grasses and in red clover when sown in mixtures and "put up" to hay at four contrasting dates: first harvest year, 1927: E. 72 I—IV: Gorse Field.*

Reference number	I.	II.	III.	IV.	Average.
Date of "putting up" to 1927 hay	October.	February.	April.	May.	
Tall oat grass	2,389	1,645	1,535	543	1,528
Cocksfoot (commercial)	449	415	268	164	324
Cocksfoot (indigenous)	184	126	159	122	148
Meadow fescue	431	565	613	315	481
Timothy	281	409	348	288	332
Crested dogstail	506	520	659	326	503
Red clover (Montgomery)	3,293	3,693	4,230	3,045	3,565
Average	1,076	1,053	1,116	686	..

In Table XLIII the average weights in milligrammes per plant (first year hay) are summarized. Comparing the species, the high relative productivity of red clover in contrast to the best of the grasses is significant, and shows how it is that red clover is capable of such high aggregate productivity in hay. Among the grasses, yield per plant in the hay appears to be positively correlated with stemminess at mid-season. Tall oat grass gives a heavy, although very stemmy yield, whilst the high position attained to by crested dogstail is of considerable interest. The highly leafy indigenous cocksfoot, on the contrary, does not show to advantage against the more stemmy commercial strain. Vigour as estimated by size of plant in hay is, therefore, very far from indicating relative values as between species or as between strains within the species.

On the whole, the effect of date of " putting up " to hay upon vigour per plant has been directly comparable with those data already discussed in relation to total yields. Taking the average of all species (excepting Italian rye-grass) it is shown that the average size of plant has not been greatly affected by late grazing. Closer analysis will show, however, that whereas tall oat grass and, to a less degree, commercial cocksfoot are lowered in respect of yield per plant in hay by being grazed in the spring, the medium early and late grasses as well as red clover are by virtue of the lessened competition from rye-grass able to produce larger plants unless the grazing is carried on into May, when even Montgomery clover will have awakened to active productivity and will be harmed very appreciably by the grazing.

TABLE XLIV.—*Showing the number of panicles per plot* (= 1/400*th acre*) *in five grasses sown in mixtures and " put up " to hay at four contrasting dates : first harvest year hay* 1927 : *E.* 72 I—IV : *Gorse Field.*

Reference number	I.	II.	III.	IV.
Date of " putting up " to 1927 hay ..	October.	February.	April.	May.
Tall oat grass	769	750	931	160
Cocksfoot (indigenous and commercial)	265	366	449	110
Meadow fescue	876	1,402	1,106	576
Timothy	209	329	458	381
Crested dogstail	977	1,219	1,638	1,286
Total per plot (= 1/400th acre) ..	3,096	4,065	4,582	2,513
Relative	100	131	148	81

(*f*) *Total Production of Panicle Shoots.*

The data given in Table XLIV are in terms of panicle per 1/400th acre plot and these show that the amount of flower production in the grasses increases as competition from Italian rye-grass is lessened by spring grazing. In this respect species do not appear to fall into any well marked classes according to earliness or lateness of spring growth. Tall oat grass, for example, behaves in

general similarly to the other species, making its maximum flower production when " put up " to hay in April. When grazing is carried into May, all species fail to produce as many panicles as when " put up " in April. It is, however, of interest to note that whereas species of early growth when grazed till May fall very far short of the panicle numbers found in part III (grazed until April), yet in timothy and crested dogstail, both grasses which awaken to growth very late in the spring, there has been only a slight fall in panicle production. In each of these latter cases the number of inflorescences given in part IV is in excess of the numbers found in part I (" put up " in October) where there was excessive competition from Italian rye-grass and/or cocksfoot and tall oat grass.

The results therefore show that competition has a very marked effect upon panicle production in the grasses, and when competition is lessened, as by spring grazing, there is an increase in the amount of flowering. Grazing as late as May 13th, however, considerably reduces the vigour of flower production, which result is most pronounced in species making early spring growth, such as tall oat grass (see Table XLIV) and Italian rye-grass, as indicated by detailed observations made on the plots.

TABLE XLV.—*Showing the percentage establishment in the first harvest year of certain grasses and red clover sown in mixtures and " put up " to hay at four contrasting dates* 1927 : *E.* 72 I—IV : *Gorse Field.*

Reference number	I.	II.	III.	IV.
Date of " putting up " to 1927 hay ..	October.	February.	April.	May.
Italian rye-grass	25.5	23.8	19.5	16.8
Tall oat grass	17.5	19.3	13.6	11.6
Cocksfoot (indigenous and commercial)	15.0	15.9	14.7	16.6
Meadow fescue	11.7	12.6	12.5	13.6
Timothy	7.9	8.8	9.8	8.5
Crested dogstail	20.3	21.6	21.4	28.1
Rough-stalked meadow grass	6.5	6.2	6.7	6.6
Montgomery red clover	15.2	19.0	21.7	22.3
Averages.				
(*a*) All the species	15.0	15.9	15.0	15.5
(*b*) Without Italian rye-grass and tall oat grass (early grasses) ..	12.8	14.0	14.5	16.0

(*g*) *Percentage Establishment of Viable Seed* (*First Harvest Year*).

Percentage establishment data are given in Table XLV, and it is shown that late spring grazing has definitely reduced the establishment in Italian rye-grass and tall oat grass as compared to parts I and II where little or no grazing was carried out. This decrease in numbers can be directly attributed to the killing of plants consequent upon repeated defoliation when spring growth has actively begun. Stapledon (15) has shown that repeated cutting at this period has a marked influence upon persistency as well as upon productivity. Furthermore, this early defoliation of species productive in the spring may be sufficient to weaken them to the extent that the later growing species and notably red clover may become truly aggressive in the hay, actually killing off the weakened

plants of Italian rye-grass and tall oat grass by excessive shading. There is abundant evidence to show that grazing late into the spring results in a decrease in numbers of plants belonging to species of early spring productivity.

In respect of the other (later starting) species in the herbage, the evidence appears to be equally conclusive, and shows that under the conditions of the trial there was an actual increased establishment on plots " put up " in May compared with those not grazed during the spring period. There are at least two probable explanations of this comparative increase in number. Firstly, the competition from the early growing species is lessened and therefore any weakly plants are afforded a better chance of development ; and secondly, there are good reasons for supposing that whilst latency in herbage seeds is increased by intense sub-aerial competition, the germination of such " latent " seed is hastened by consolidation of the surface soil caused by the treading of the sheep used as a grazing instrument.*

The influence of contrasting seed rates of Italian rye-grass upon establishment will be discussed in the following section of this paper.

(2) *The Effect of Competition upon Yield and Botanical Characters of the Hay.*

(*a*) *Total Yield of Hay in the First Harvest Year.*

The main purpose of the experiment was to investigate how far aggressiveness is controllable by intermittent and methodical grazing in the spring. The data, however, allow of further analysis and show the effect of Italian rye-grass

TABLE XLVI.—*Showing the air-dried yields of hay in cwt.* (= 100 *lb.*) *per acre, from a number of herbage species sown in mixtures : influence of four contrasting seed rates of Italian rye-grass : first harvest year* 1927 : *E.* 72 I—IV : *Gorse Field.*

Species.	Seeding of Italian rye-grass per acre.				Yields in column 4 with those in column 1 at 100.
	No rye-grass.	4 lb.	10 lb.	16 lb.	
Italian rye-grass	..	14.66	18.11	18.90	..
Tall oat grass	7.36	3.08	1.54	1.29	18
Cocksfoot (indigenous and commercial)	7.99	3.12	1.67	1.24	16
Meadow fescue	12.30	3.09	0.80	0.35	3
Timothy	7.19	3.03	1.39	1.03	14
Crested dogstail	7.47	3.86	2.26	1.96	26
Rough-stalked meadow grass ..	1.64	0.41	0.24	0.31	19
Montgomery red clover ..	18.54	16.27	16.17	13.96	75
Wild white clover	0.24	0.18	0.22	0.23	..
Weeds (= unsown plants) ..	2.55	0.85	1.09	0.81	..
Total (*not* per acre)	54.33	45.47	41.20	39.10	..

* Trials in connection with these problems are in progress at the Station.

and other aggressor units upon the several contributory species in the herbage. In Table XLVI are given the average hay yields for each species when grouped according to the seeding of Italian rye-grass in the mixture. The data confirm other results recorded in this bulletin showing Italian rye-grass to have a profound effect upon potential hay yields of other species in the herbage. Meadow fescue again takes its place as a plant highly sensitive to aggressiveness, even 4 lb. per acre of the rye-grass reducing the hay yield of the fescue by 75 per cent., whereas heavier seedings of the former practically eliminate the latter as a successful contributor to the hay. Similar results are apparent in respect of the other grasses and clovers, each reacting in a more or less marked degree to the influence of competition. Red clover in the main is not so much affected as the grasses by Italian rye-grass, but there is evidence to show that clover yields are considerably reduced by heavy seedings of cocksfoot. In the present comparisons, therefore, when Italian rye-grass is added to the seeds mixture it replaces competition exerted by cocksfoot in the "no rye-grass" plots; this replacement is, however, considerably more serious in its reaction on the grasses in general than on red clover.

TABLE XLVII.—*Showing average percentage productivity (estimation) of the sown species and weeds in aftermath: plots with contrasting seedings of Italian rye-grass: first harvest year* 1927: *E.* 72 I—IV: *Gorse Field.*

Reference number to mixture ..	5	6	7	8
Seeding of Italian rye-grass in lb. per acre	No rye-grass.	4	10	16
Italian rye-grass	..	16.0	21.0	28.2
Cocksfoot (indigenous)	45.6	29.9	20.4	12.9
Other sown grasses	21.8	20.7	19.8	17.7
Montgomery red clover	28.9	29.4	34.6	34.9
Wild white clover	0.7	0.8	0.5	1.0
Weeds (= unsown plants)	3.0	3.2	3.7	5.3
Total	100.0	100.0	100.0	100.0

The percentage productivity data (aftermath) of a representative section of the experiment are given in Table XLVII, and make an interesting comparison with the hay results of the first harvest year. The sown grasses other than Italian rye-grass and cocksfoot are conveniently grouped together: the clovers are treated individually. The results indicate that Italian rye-grass is not so aggressive as an aftermath plant as it has proved itself to be during the spring. Table L (see page 143) demonstrates that Italian rye-grass has not abnormally depressed the establishment of Montgomery red clover, and there is every indication to show that cocksfoot was the more aggressive towards the clover. In Table XLVI it has been shown that Italian rye-grass markedly depressed the yield of late red clover in the hay crop. Cocksfoot is relatively non-aggressive in first year hay, but by virtue of a potentiality for high yields of leafy aftermath it becomes highly aggressive during the post-hay period. If, however, the establishment and growth of cocksfoot have been unduly

depressed by Italian rye-grass in the hay and pre-hay growth stages, the former is unable to make sufficient recovery to act as an aggressor in first year aftermath.

Table XLVII shows that Montgomery red clover gives a lower percentage yield of aftermath with cocksfoot and no rye-grass than where heavy seedings of rye-grass have been sown. The percentage of red clover appears to be inversely proportional to the percentage contribution of cocksfoot, showing the latter to be decidedly aggressive under these conditions. In short, it may be concluded that Italian rye-grass whilst being highly aggressive towards late red clover during the spring period does not have as great an effect upon the clover in aftermath as does cocksfoot. The depressant effect upon establishment of red clover in the " no rye-grass " plots (Table L) is probably attributable to the heavy seeding year productivity of cocksfoot in this experiment.

The residual influence of competition exerted by rye-grass upon the grasses in hay is still apparent in the aftermath (Table XLVII)—the productivity of the sown grasses (other than rye-grass) being in inverse ratio to the seeding of Italian rye-grass. The weeds in aftermath appear to be most abundant with heavy rye-grass seedings.

TABLE XLVIII.—*Showing the influence of four contrasting seed rates of Italian rye-grass upon the yield per plant of other species in the hay crop: weights in milligrammes per plant: 1927 first harvest year: E. 72 I, " put up " October, 1926. Gorse Field.*

Reference number to seeds mixtures*	1.5.9 :	2.6.10 :	3.7.11 :	4.8.12 :
Seeding of Italian rye-grass in lb. per acre	No rye-grass.	4	10	16
Cocksfoot (commercial)	1,307	230	140	118
Cocksfoot (indigenous)	492	172	55	18
Meadow fescue	1,245	305	130	45
Timothy	696	263	112	50
Crested dogstail	1,383	411	148	82
Tall oat grass	6,553	1,438	925	639
Montgomery red clover	4,430	3,573	2,937	2,233
Average	2,301	913	635	455
Relative, " no rye-grass " at 100 ..	100	40	28	20

* See Table XXXIX for details of seeds mixtures.

(b) Yield per Plant in the Hay (= Vigour).

The average yields in milligrammes per plant for individual species are shown in Table XLVIII. These data are in respect of plots " put up " to hay in October, 1926 (E. 72 I) and therefore represent the extreme of competitive influence. Interesting information is, however, given as to the means whereby intense competition occasions lower aggregate yields. Italian rye-grass, by virtue of its potential capacity for making early spring growth is able to check the growth of other plants, reducing their vigour and thereby reducing total yields. Suggestions as to means of controlling competition and at the same

time employing Italian rye-grass as a constituent of seeds mixtures have been made in this paper, and take the form of methodical grazing in the spring. On the plots "put up" on May 13th (part IV) where Italian rye-grass had been controlled by spring grazing, the differences in average yield per plant were not so marked as those due to differences in the seed rate of Italian rye-grass when the plots were "put up" in October. In fact, the influence of heavy seedings of the rye-grass had been largely counterbalanced, as shown by the following statement which represents the average yield per plant (in milligrammes) on the plots put up in May :—

	Per acre.			
Seeding of Italian rye-grass in mixture	—	4 lb.	10 lb.	16 lb.
Average yield per plant (milligrammes) of species other than Italian rye-grass	904	628	552	657

These figures are interesting when considered in connection with the comparable averages given in Table XLVIII. Grazing into May has caused a marked reduction in the average figure on the "no rye-grass" plots, indicating reduced vigour in the generality of species due to late spring grazing. Where Italian rye-grass was sown in the mixture, however, there has been no great loss in yield per plant in other species when grazed late into the spring ; in fact, where the rye-grass was sown in excessive amount, the average figures show an actual increase due to spring grazing consequent upon the removal of the intense competition exerted by unhampered Italian rye-grass.

There is no need to dwell on further points arising from these data : they are in complete agreement with those already discussed in connection with other experiments reported upon in this bulletin. It may, however, be pointed out that it is the species of slowest growth from seed that are most seriously checked by Italian rye-grass ; the growth of grass is retarded far more than that of red clover.

TABLE XLIX.—*Showing the average number of panicles per plot* (= 1/400*th acre*) *in hay : influence of Italian rye-grass at four contrasting seed rates upon panicle production in five grasses : first harvest year* 1927 : *E.* 72 I—IV : *Gorse Field.*

Species.	Seeding of Italian rye-grass per acre.			
	No rye-grass.	4 lb.	10 lb.	16 lb.
Tall oat grass	1,470	573	327	239
Cocksfoot (indigenous and commercial)	650	348	130	62
Meadow fescue	2,961	834	107	33
Timothy	800	367	116	95
Crested dogstail	2,244	1,324	838	714
Total	8,125	3,446	1,518	1,143
Relative	100	42	19	14

(*c*) *Production of Panicle Shoots.*

The influence of contrasting seed rates of Italian rye-grass upon panicle production in the other grasses is shown in Table XLIX. Italian rye-grass is seen to have been effectual in reducing the capability to flower in the grasses when grown under competitive conditions. Compared with the " no rye-grass " plots, a seeding of 16 lb. per acre of Italian rye-grass has on the average reduced the relative number of grass panicle shoots in the hay of the first harvest year from 100 to 14. These data, therefore, give further indications as to reasons for the heavy reduction in yields of hay consequent upon conditions of excessive competition.

Italian rye-grass naturally has its greatest effect upon flowering in other species when spring growth is allowed to grow unchecked. That this is true is shown by the following statement which represents the total number of panicles per 1/400th acre in five grasses,* when mixtures containing no Italian rye-grass and 16 lb. per acre of Italian rye-grass respectively are " put up " to hay at two extreme dates :—

Panicles per 1/400th acre plots in first harvest year hay (1927).

Date of " putting up " to hay.	1926. October.	1927. May.
No Italian rye-grass in mixture	8,268	3,792
16 lb. per acre Italian rye-grass	531	1,757
Ratio—No rye-grass : with 16 lb. Italian rye-grass	100 : 6	100 : 46

These figures show that grazing even into May does not reduce vigour of flower production to as great an extent as do excessive seedings of Italian rye-grass. By a properly adjusted system of spring grazings with consequent control of competition, the vast majority of the grasses are able to flower more freely in the hay crop than when hampered by excess of Italian rye-grass.

(*d*) *Percentage Establishment of Viable Seed* (*First Harvest Year*).

Percentage establishment data for the experiment available for the first harvest year are given in Table L. Taking the average results for species other than Italian rye-grass, it is found that the percentage establishment is in inverse ratio to the amount of rye-grass sown. Similar results have been recorded in other experiments dealing with competition in temporary grass, but it is to be noted that in the present trial Montgomery red clover and crested dogstail do not conform to the general rule. Both species do not start normal spring growth until late in the season, and indeed are almost dormant up to such time as Italian rye-grass is ready to run to flower, and consequently becomes stemmy and less aggressive as an element in the competition complex. The relative establishment of Italian rye-grass sown at the contrasting seed rates

* Tall oat grass, cocksfoot, meadow fescue, timothy, and crested dogstail.

TABLE L.—*Showing the average percentage establishment of viable seeds in a number of species sown in mixtures: influence of Italian rye-grass at four contrasting seed rates upon establishment in the first harvest year* (1927): *E. 72* I—IV: *Gorse Field.*

Species.	Seeding of Italian rye-grass per acre.			
	No rye-grass.	4 lb.	10 lb.	16 lb.
Italian rye-grass	..	32.0	18.6	13.6
Tall oat grass	18.9	16.5	13.6	12.9
Cocksfoot (indigenous and commercial)	17.7	16.7	14.1	13.7
Meadow fescue	19.1	11.0	11.1	9.2
Timothy	11.9	8.7	7.6	6.8
Crested dogstail	20.7	23.9	24.3	22.5
Rough-stalked meadow grass	7.6	6.6	6.4	5.4
Montgomery red clover	18.3	18.1	19.0	22.7
Average establishment without Italian rye-grass	16.3	14.5	13.7	13.0
Relative	100	89	84	80

is of interest, and shows that intra-specific competition or competition exerted within the species is an important factor in sward production.

Establishment in herbage plants when sown in a mixture is, however, generally poorer than in pure plots where only intra-specific competition is to be contended with. Detailed reports dealing with establishment in pure plots have been published in an earlier bulletin. The statement given hereunder demonstrates the lowering of average "take" when species are sown in a seeds mixture. The data for "pure plots" are extracted from a previous report by Davies (5), while the seeds mixture figures are from the present experiment :—

Average percentage establishment of 7 species of grasses and clovers.*	
Average of 7 species in pure culture plots	23.9 per cent. (100)†
Average of the same 7 species in seeds mixtures	14.4 per cent. (60)†

These data are amply confirmed by a considerable number of seeds mixture trials conducted at the Station, and show that competition within a seeds mixture causes a considerable reduction in establishment, and moreover this is likely to over-ride any correlation between size of seed and average soil establishment as was shown by Davies (5) to exist on pure culture beds.

* Meadow fescue, cocksfoot, timothy, crested dogstail, tall oat grass, rough-stalked meadow grass, and red clover.

† Relative with "pure plots" at 100.

E. 72 : Summary to the Experiment.

(1) The effect of date of " putting up " to hay and the influence of Italian rye-grass upon the yield and composition of first year seeds hay have been critically elucidated.

(2) It has been shown that Italian rye-grass as an aggressor species in the hay crop may cause lower aggregate yields in other grasses and clovers. The lower productivity is attributable to reduced yields per plant (which embraces suppression of flower production), and in most species to a reduction in the number of plants as measured by percentage establishment of the viable seeds.

(3) Both Italian rye-grass and tall oat grass are aggressive in hay by virtue of their capacity for making growth early in the spring. The influence of such aggressor species can, therefore, be largely controlled by a methodical system of intermittent grazing during the spring. It has been shown that Italian rye-grass can with advantage be included in seeds mixtures for the special purpose of producing spring pasturage. Its utilisation for this purpose results in the provision of highly valuable grass at a period of the year when the flockmaster is in urgent need of keep. The suppression of Italian rye-grass by grazing reacts to the benefit of the June hay crop.

(4) Grazing carried on into late spring makes for the production of light, immature hay crops, which by virtue of their immaturity are highly leafy and therefore highly nutritious. Although the total yield of hay may be thus lowered, the total production of nutrient food is not greatly reduced, and there are indications that the total cash values of the crops—having due regard to the nature of the spring pasturage—may be at their maximum consequent upon late " putting up " to hay.

SUMMARY AND GENERAL CONCLUSIONS.

(1) The investigations reported upon in this paper have in the main dealt with the influence of inter-specific competition in seeds mixtures. The results embrace critical analyses carried out on swards in the seeding year and in the first to fourth harvest years.

(2) During the seeding year a species is aggressive in proportion as it is capable of rapid establishment from seed, and in proportion to its total productivity and tillering capacity during the early growth stages. The rye-grasses at this period are highly aggressive : they germinate and establish themselves rapidly, and have a potentiality for seedling development not excelled by any of our British grasses.

(3) The ability to withstand competition in the first harvest year is largely determined by the earliness and amount of growth made in the spring. A species that develops early in the spring is aggressive towards one that is relatively late in starting active growth. The late species are therefore handicapped as hay plants by the accumulated growth made by earlier species. If such accumulated growth is continually removed, however, at a time corresponding to the awakening period* of the later species, it is the latter which may become aggressive during the period allowed for unhampered hay development.

* See Stapledon (15).

Thus Italian rye-grass, which begins active growth early in the spring, if unchecked will be aggressive towards all strains of red clover. If, on the other hand, this spring growth is removed by judicious grazing, the late flowering strains of red clover may become aggressive (during the hay producing period) to the weakened rye-grass.

(4) Subsequent to the first harvest year, and particularly in the later harvest years, competition between sown species is largely connected with the persistency and vigour of growth of the individual plants. Species which are able to gain ground either by re-seeding or by vegetative development are likely to be more aggressive than species incapable of adding to the number of established plants, despite the fact that individual plants may be very highly persistent and particularly long lived.

Rough-stalked meadow grass, wild white clover, meadow foxtail, *Agrostis* spp., and to a less extent tall fescue are species which are non-aggressive in the earlier years of a sward developed from a seeds mixture—provided the definitely aggressive species have been well established from sowing. They are species, however, which are likely eventually to become highly aggressive, particularly under pasture conditions, by virtue of being endowed with well developed means of vegetative propagation.

In like manner crested dogstail, Yorkshire fog, and sweet vernal grass are frequently aggressive because of their undoubted capacity for self-establishment from seeding—a common happening on swards which are not properly grazed or which are not run over when necessary by the mowing machine.

A species or strain will also be aggressive under pasture conditions in later harvest years in proportion to its ability to withstand heavy grazing.

(5) Competition in relation to seeds mixtures where hay is taken is largely a function of sub-aerial shading, and hence the most aggressive species under such conditions are those which can successfully shade and thereby weaken and/or kill off plants of other species. Conversely, the unsuccessful competitor is one which does not tend to handicap other species to any marked degree, and which itself cannot withstand excessive shading ; meadow fescue and timothy belong to this latter category.

Root competition does not appear to be a factor of prime importance in relation to seeds mixtures, except possibly on poor soils and under the poorest conditions generally. That root competition is not a decisive factor is suggested by the fact that Italian rye-grass is equally aggressive towards rough-stalked meadow grass (shallow rooted), meadow fescue (deeper rooted), red clover (deeply rooted), and lucerne (very deeply rooted).

(6) Competition lowers both soil establishment and vigour of growth in all but the most aggressive species. Yields are therefore reduced consequent upon excessive competition.

(7) Excessive crowding either in pure species or in mixtures reduces the potentiality for stem and flower production, and consequently overcrowding lowers both hay and seed yields. The latter is an important point in connection with seed production. Intense competition also reduces length of inflorescence, thus further indicating that competitive interaction in seeds mixtures is largely due to shading and reduced light (duration and intensity) available to the non-aggressor species.*

* See Tincker (22) and Brenchley (3).

(8) The whole trend of competition between the several species included in a mixture is given a fundamental direction by the methods of management adopted. Species can be classified as potential aggressors or as potentially sensitive to competition. Everything will of course depend upon whether the aggressor species are allowed to develop unhampered and to exercise their maximum effect.

(9) All competitive effects are, however, to some extent reciprocal, so that although an aggressor species will greatly hamper the more sensitive species, the latter are likely also to react to some extent on the development of the former.

(10) Speaking broadly, the grasses compared to the clovers are the aggressor species—this is largely due to the fact that most of the grasses start growth earlier in the spring than do the clovers. This is not to say, however, that clovers are incapable of hampering the development of the grasses.

(11) Grass yield under conditions favourable to the development of the red clovers is more or less in inverse proportion to the yield of the clovers. Thus, at low elevations and under conditions of high fertility, grasses yield more heavily with broad red clover or with wild red clover than with the highly productive late flowering red clover. At high elevations and under conditions of low fertility—where low fertility is the chief limiting factor to growth and where the clovers do not attain to sufficient luxuriance to hamper the grasses to any appreciable extent—the yield of grasses tends to be high in proportion as the yield of clovers is high—in proportion, that is to say, to the influences of the clovers on soil fertility.

(12) The influence of the clovers on each other is such that during the seeding year broad red may be regarded as the aggressor. By establishing itself more rapidly from seed than the late flowering strains, it exerts a smothering effect upon late clovers from the outset, an effect that may still be apparent in the subsequent hay crop. During the spring of the first harvest year again broad red clover, by virtue of making earlier spring growth than late red clover, may exert a deleterious influence. When, however, the late flowering strains begin active growth after fields have been " put up " to hay they can be aggressive to broad red clover, especially in seasons when the early red strains have overwintered badly and have thinned out in consequence. The late reds not only have a potential ability for making very rapid growth in late spring and early summer, but they tiller more abundantly than broad red and hold up their leafage to better advantage. During the active hay producing period of growth the late clover rather than the early will consequently tend to be the aggressor strain. Williams (23) has shown that good stands of broad red clover are aggressive to the extra late red clovers (*e.g.* Montgomery) in first harvest year aftermath.

As between broad red and alsike, the former must be regarded as the aggressor in both the seeding and the first harvest years. Late flowering red clover has a still more pronounced depressant effect upon alsike.

All the larger clovers are aggressors in relation to wild white clover. Generally speaking, late flowering red clover exercises a greater retarding influence on wild white clover than does broad red or alsike, partly because the former is responsible for very heavy hay crops in the first harvest year and partly because there is further considerable competition set up in the second

harvest year. Broad red clover may, however, be very highly aggressive to wild white if excessive growth is made in the year of seeding.

(13) The influence of the clovers on the grasses is fundamentally affected by two factors of management—the date at which the field is " put up " to hay and the date of cutting the hay. The longer the grazing is continued in the spring, the greater will be the hampering effect on the " early " grasses than on the " late " clovers ; while in proportion as the hay is cut late, so will late flowering red clover be favoured. Under these conditions late flowering red clover may become the absolute aggressor species in the mixture. Under more or less normal conditions late flowering red clover competes more favourably with the aggressor grasses than does broad red clover, while when sown in conjunction with late timothy the late clover is definitely the aggressor species.

(14) The influence of the grasses on the larger clovers under normal conditions of management is usually considerable. In one-grass-one-clover mixtures cocksfoot exercises quite as marked a retarding influence on the clovers as do the rye-grasses, while even when fields are " put up " early, perennial rye-grass exercises as much influence on late flowering red clover as does Italian rye-grass ; the effect of the latter grass on broad red clover is, however, always the greater. The early tall oat grass has exercised as great a retarding influence on the broad red clovers as has Italian rye-grass. Timothy interferes with clover development less than do any of the larger grasses.

The addition of either or both of the rye-grasses to mixtures containing other large hay grasses exercises a marked suppressing effect on the red clovers—thus the red clovers are more hampered in mixtures containing two or more hay grasses, one of which is a rye-grass, than they are in mixtures containing but one hay grass—and this seems to be the most important point to bear in mind relative to the effect of both Italian rye-grass and perennial rye-grass on red clover development.

The influence of rye-grass on clovers is in proportion to the seed rate of the rye-grass.

(15) It is with reference to the influence of one grass on another and on wild white clover that Italian rye-grass has to be considered as the major aggressor species. It is furthermore on this account that management exercises such a profound effect on the trend of competitive influences. When fields are grazed long into the spring, right into May, for example, the rapid, early growing Italian rye-grass affords most of the keep available. Consequently it is this species that is most harmed by the treatment, with the result that its contribution to the hay is greatly reduced and its competitive effects on the other species proportionately minimised. The effect of this aggressor species, is, however, by no means completely eliminated even when grazing is continued into May, while it will be quite appreciable if grazing is continued only up to the middle of April, although not nearly so well marked as when fields are " put up " soon after Christmas. The full effect of Italian rye-grass is only to be seen when fields are " put up " some time before spring growth normally commences.

The competitive influence of Italian rye-grass is much increased by increases in the seed rate, although as little as 4 lb. to the acre on fields " put up " early will have a very real influence on the other species contributing to the mixture.

Tall oat grass, another early grass, is to be ranked as an aggressor species, although it seldom exercises its full potential effect because good stands of this

species are seldom achieved. It is in itself highly sensitive to seeding year competition with Italian rye-grass.

In the aggressor scale perennial rye-grass is to be ranked next to Italian rye-grass—as is shown by the fact that the development of Italian rye-grass is retarded more by association with perennial rye-grass than with any other species. Like Italian rye-grass, perennial is aggressive in more or less direct proportion to the seed rate. Although cocksfoot is as aggressive relative to the red clovers as perennial rye-grass, the rye-grass is definitely aggressive towards cocksfoot.

Cocksfoot is the aggressor relative to timothy and to meadow fescue—these two species being the most sensitive to competition of all the larger hay species.

(16) Some species whilst being wholly non-aggressive in hay are yet able to withstand a fair degree of competition from aggressor species—rough-stalked meadow grass and crested dogstail are examples. On poor soils the dogstail appears to be less sensitive than the meadow grass, while conversely on highly fertile soils rough-stalked meadow grass is the less sensitive, as is shown by the good contribution it often makes to the hay of the second harvest year.

Meadow fescue, while being highly sensitive to competition more especially during the seeding and first harvest years, can, when once fully established, stand a considerable amount of competition. Similar remarks would apply to tall fescue and to meadow foxtail.

(17) The species and strains of herbage plants dealt with at the Station may be grouped as follows according to their potential aggressiveness :—

A. Aggressors.

(1) *Aggressive in the seeding year—*
Italian rye-grass, perennial rye-grass, tall oat grass, broad red clover, cocksfoot,* late flowering red clover.

(2) *Aggressive in first harvest year hay—*
Italian rye-grass, perennial rye-grass, tall oat grass, late flowering red clover, broad red clover, cocksfoot.†

(3) *Aggressive in the aftermath—*
Italian rye-grass, cocksfoot, broad red clover, late flowering red clover, tall oat grass.†

(4) *Aggressive in pastures—*
Rough-stalked meadow grass, bent, wild white clover, crested dogstail, Yorkshire fog, suckling clover.

B. Generally non-aggressors.

(1) *Able to withstand some competition in the first harvest year or at least to make good recovery in later years.*

(*a*) *Recovery by re-seeding.*
Subterranean clover, crested dogstail, sweet vernal grass, Yorkshire fog.

(*b*) *Recovery by vegetative propagation.*
Rough-stalked meadow grass, meadow foxtail, wild white clover, tall fescue,‡ smooth-stalked meadow grass, red fescue.‡

* Especially the commercial strains.
† Usually not highly aggressive under the respective headings.
‡ Slight recovery only.

(2) *Unable to withstand keen competition and to make recovery in later years.*
Meadow fescue, timothy, bird's foot trefoil, alsike, sheep's fescue.

(18) The effects of competition become exaggerated under conditions of low fertility—perennial rye-grass becoming highly aggressive, the two rye-grasses together enormously handicapping the development of other species. Late flowering red clover, which does not appear to be as high a fertility-demander as broad red clover, is perhaps the species most competent to compete with the rye-grasses under such conditions : a consideration which renders it doubly important that the red clover should always be the representative of a good late flowering strain at high elevations.

(19) Intense competition during the early years of the ley increases the tendency to latency and delayed germination of sown seeds. This is especially pronounced in the less aggressive species. Adverse conditions generally, as exampled by late sowings or excessive competition, tend to favour delayed germination.

(20) Investigations dealing with persistency of sown species and strains have been carried out at the Station, and a few of the preliminary results covering a four-year period have been embodied in the present paper. It has been found that the whole problem is complicated by the phenomenon of delayed germination.

(21) As reported in an earlier bulletin, spring sown seeds mixtures give the best results, at least in the higher rainfall areas of Britain. There are indications, however, that autumn sowings, although giving very low primary establishment, promote considerable latency in sown seeds, which remain dormant until favourable conditions arise in the following spring.

(22) The development of seeds mixtures under a cereal crop tends to be hampered by the so-called "nurse."

Cereals as a general rule, however, tiller less abundantly than do the more aggressive grasses during the seeding year. It follows that a cereal crop may prove a less aggressive competitor than the rye-grasses if these grasses are allowed to make full and active growth during the seeding year. Thus mixtures including the rye-grasses and sown without a nurse crop may be more hampered than those sown with a cereal (since the cereal hampers the rye-grasses) unless the autumnal grazing is properly regulated.

(23) In Wales, and presumably in similar high rainfall areas of Britain, it would appear that maximum soil establishment of herbage plants is to be achieved by sowing without a cereal. It is a sound practice to sow under rape or other appropriate crucifer and to start a well regulated scheme of intermittent grazing about 8 to 10 weeks after sowing. Sheep are ideal animals for the purpose. Seeding year competition is thus reduced to a minimum and the surface soil is, moreover, efficiently consolidated by the grazing animal—soil and seedlings being firmly pressed together. In regard to mixtures designed for long term leys or permanent grass it is best to graze on a careful intermittent basis right through the first harvest year, or to take a light hay crop when the grazing should be carried on far into the spring and the hay none the less cut reasonably early.

SENSIBLE SEEDS MIXTURES.

by

R. G. Stapledon, M.A., and Wm. Davies, M.Sc.

Introduction.

The various experiments dealt with in the previous papers have a very direct bearing on the compounding of seeds mixtures. In this concluding article an endeavour is made to translate these results into terms of practical precepts. The suggestions here made are, however, also founded on results from trials not dealt with in this bulletin* and from experience gained by one of us in connection with seeds mixture studies conducted in Wales during the past 15 years. The actual mixtures now advocated are in many cases entirely different from those which a decade ago were prescribed by the then Adviser in Agricultural Botany, despite the fact that the person in question is a joint author of the present paper. A dozen years ago advice had to be given very largely on text-book dicta, the adviser of those days having behind him no critical data based on accurate trials conducted in the area of which he was assumed to have a complete knowledge. The present advice is of an eminently different order, being the outcome of accurate experimentation, and consequently it is hardly to be expected that it should be on all fours with that freely, and of necessity freely, given in the earlier days.

Factors which determine the success of Seeds Mixtures.

Baldly stated, the following are the more important factors which determine the success of seeds mixtures : or rather it is a proper appreciation of the manner of operation of these factors which should determine the character of the mixture employed for any given set of conditions :—(1) The explicit use to which the resulting sward will be put ; (2) The propensity of the various species and strains to the various habitat relationships to be catered for ; (3) The characteristics of the seed of the various species and strains, *e.g.* average viability, grain weight, and potentiality for soil establishment ; (4) The conditions most favourable to soil germination and establishment of the several species and strains ; (5) The competitive influences of one species upon another and the effect of differential management on such influences ; (6) The general balance of the resulting sward ; (7) The response to management of the species.

The explicit use to which the Resulting Sward will be put.

Duration.—All the evidence at our disposal strongly suggests that seeds mixtures should be adjusted according as the sward is required for (*a*) eighteen months or less ; (*b*) two harvest years ; or (*c*) three or more harvest years. The distinction between " long leys " and " permanent grass " is not a seeds mixture

* Many of these trials have already been reported upon, while others are still in progress and will be dealt with in detail in a subsequent bulletin.

distinction—a good three year ley, or particularly a good four year ley, will require precisely the same seeds mixture treatment as the production of a good 30 or 40 year permanent sward.

Purpose.—It is "purpose" much more than "duration" that should predetermine the choice of a seeds mixture. It is a first necessity to decide whether hay or grazing is chiefly desired—"hay" and "grazing" are not compatible—rather less compatible than the attributes desired of the "dual-purpose" animal. Broadly speaking, from the "purpose" point of view, as envisaged by the farmers of today, mixtures may be divided into four major classes : (*a*) For grazing only, *i.e.*, for the production of swards from which a hay crop will never be taken ; (*b*) hay the first consideration, *i.e.*, for the production of swards from which very heavy crops will be looked for over the whole life of the ley—such fields will be "put up" early and cut rather late ; (*c*) hay for the first and (or) second harvest year(s) followed by two or three further harvest years for grazing only,—this is the most difficult type of dual purpose management adequately to cater for from the seeds mixture point of view, and yet this is what is most commonly expected of a temporary ley ; (*d*) hay and grazing regarded as of equal importance, the ley being expected to yield a hay crop and abundant grazing during each year of its existence. The management of leys on this latter basis accords most nearly with the teaching of modern grassland research—a type of management which need not run counter to the incompatibilities of species and strains to any considerable extent, provided the mixture is properly blended.

Seasonal.—The value of herbage is at its greatest when production is at its lowest—consequently eatable and nutritious herbage from November to May is altogether more valuable per lb. of green grass than from May to November. Winter-green grasses—perennial rye-grass, crested dogstail, and rough-stalked meadow grass are pre-eminent—are therefore of immense value in swards. Almost equally valuable are grasses that will start growth early in the spring and maintain growth long into the autumn—cocksfoot and meadow foxtail start early in the spring ; perennial rye-grass makes good late autumn growth. Italian rye-grass is, however, the outstanding November-May grass, for it will make better winter growth than any other species, and if grazed on a proper intermittent basis may be maintained in a condition of almost complete winter-greenness.

The clovers are of negligible significance during the winter : the red clovers are, however, of great value in the autumn, and contribute a very important quota to the grazing after the zenith period of growth of the grasses, namely, in July, August and September ; the extra late red clovers (Montgomery and Cornish marl) are of particular value at this time of the year, and especially in seasons of drought.

Propensity.—It may fairly be stated that the value of a particular species for a particular habitat is a direct function of the amount of leaf that species will produce per acre per annum. A species will only produce the maximum of leaf of which it is capable if in equilibrium with its surroundings. Cocksfoot, for example, is able to produce enormous yields of leaf per acre under conditions suitable to it—under other conditions a grass of much lower inherent productivity (*e.g.* bent grass or red fescue) may well produce a higher yield of leafage.

The first question to be asked then in relation to the long duration leys and to all fields upon which it is desired to establish anything in the nature of a

permanent sward is this : What species are propense to the soil and climatic conditions which the field presents ? Any reasonable longevity from sown species can only be expected from such as are propense to the conditions.

This question of propensity and persistency has been sadly neglected, just because our grassland studies have been so little conducted in the true spirit of the ecologist. The problem of sowing out infertile land, land at high elevations, and land in a stagnant or semi-stagnant condition is primarily a question of propensity.

It by no means follows that the species that do well or reasonably well under average or better than average conditions are of value under poor or very poor conditions.

The trials so far conducted have shown that propensity is not only a matter of species, but is very much indeed a matter of strain within the species. Thus indigenous cocksfoot (of a good strain) is altogether more propense to high elevations of low fertility than is Danish cocksfoot. Broad red clover, late flowering red clover, extra-late red clover (Montgomery or Cornish marl), wild red clover is the order in which the strains of red clover would appear to become increasingly propense to conditions of increasing acidity and decreasing fertility. It follows that although good strains of wild red clover in comparison with excellent late flowering red clovers are little better than weeds on fertile land, they may be of supreme value on certain habitats (for example, at high elevations and on semi-stagnant clay lands). Wild white clover has a wide range of propensity, far wider than white Dutch or New Zealand clover ; but the conditions are not always suitable to even this invaluable strain of perhaps our most important herbage species. The indications are that the running may then be taken up by the bird's foot trefoils, and that *Lotus major* has a degree of propensity to some of the more difficult habitats which may come to render it a really valuable herbage plant.

It is largely because propensity has never been considered, that such highly important grasses as rough-stalked meadow grass and crested dogstail have been so neglected. Both are perfect bottom grasses, and, as has already been said, highly winter-green. Rough-stalked meadow grass, although a high fertility demander (or at all events a splendid responder to high fertility) is yet decidedly propense to relatively low fertility, provided the rainfall is high and the conditions not stagnant.

As the conditions become less favourable, crested dogstail must be more and more relied upon, and when this species makes but poor growth it is necessary to choose from species even lower in their demands upon condition. Such species are the fine-leaved fescues, the bent grasses, sweet vernal grass, and Yorkshire fog. There are indications that pedigree strains of red fescue are remarkably propense to some of the more difficult of the upland conditions in Wales—by implication, therefore, it must be conceded that pedigree strains of the bent grasses, sweet vernal grass, and Yorkshire fog would be likely to be equally propense to a number of the more difficult habitats that are annually grassed out* : habitats which run to a very large acreage in the aggregate and which it

* The whole scale of palatability is different for poor and for good conditions. Thus many plants which are neglected when growing with more palatable species are readily eaten when not associated with species or strains of supreme palatability ; under these conditions wild red clover, red fescue, and sweet vernal grass, for example, may stand high in the scale of palatability of the sum of the species contributing to the herbage as a whole.

must be admitted are extraordinarily ineffectually grassed out with the species usually included in *effective quantity* in seeds mixtures. Speaking in terms of seeds which are commercial commodities it can therefore emphatically be stated that rough-stalked meadow grass, crested dogstail, an extra-late red clover, and wild white clover should be the foundation of the seeds mixture for thousands upon thousands of acres of our poorer lands. Of seeds already obtainable to some extent, wild red clover and indigenous or New Zealand cocksfoot should be eagerly sought after, while the results from further tests with *Lotus major* should be awaited with interest.

For the rest, much may be hoped for from red fescue and not a little from the bent grasses, sweet vernal grass, and Yorkshire fog, when these species have been brought under the hand of the plant breeder.

With regard to certain species in particular propensity affords an excellent guide as to whether they should be included in mixtures. This applies with great force to wild white clover and rough-stalked meadow grass. It is true that on fields to which they are propense they will sooner or later make a strong voluntary appearance, but if sown in good amount they will immediately assert themselves with the result that a first-class sward free from weeds can be developed in no more than 8 to 15 months.

The Characteristics of the Seed.

The results reported upon in previous bulletins may be conveniently summarized in a few words, to the effect that (1) Soil establishment bears but the slightest relationship to laboratory germination ; (2) Seeds with low " energies of germination " have low powers of establishment ; (3) Small seeds have lower powers of establishment than large seeds, thus the meadow grasses have low powers of establishment, and generally speaking the indigenous strains of a species are lower in powers of establishment than the larger-seeded "commercial" strains ; (4) Seeds with low energies of germination are prone to remain latent in the soil and to form established plants slowly, if at all ; (5) The quick growing rye-grasses have higher powers of establishment than other species ; (6) Seed rate should be based on the number of established plants that may be expected per lb. of seed ; (7) On this basis the smaller seeded species require much higher seed rates than such as are generally adopted ; (8) In order to ensure the same number of plants per unit of area for each species, cocksfoot requires nearly the same seed rate as perennial rye-grass ; crested dogstail requires nearly as much, while ½ lb. of rough-stalked meadow grass (despite the very small seed) is not vastly more effective than 1 lb. of rye-grass. Meadow fescue and meadow foxtail usually have very poor powers of establishment and require proportionately heavy seed rates ; (9) Wild white clover is particularly prone to latency, as are the indigenous strains of many of the grasses.

The Conditions most favourable to Germination and Establishment.

Again briefly to summarize the results of trials previously reported upon, we may say (1) The first essential is to cover the seeds properly, sow on a dry day, cover with peg harrow and roll generously. Some species (*e.g.*, the rye-grasses) are less influenced by malpractices than others ; (2) In Wales spring sowing is preferable to autumn sowing ; late sowing is more adverse to some grasses than others, and more adverse to clovers than to the grasses ; (3) The establishing sward should be properly consolidated as soon as possible ; where adequate

rolling is impossible at the time of sowing (*e.g.*, hill fields), sheep should be brought on to the sward at the earliest possible moment. Again, the species react differently to lack of consolidation ; (4) Always roll maiden seed in the spring of the first harvest year ; (5) Heavy covering crops (of cereals), luxurious autumnal growth (*e.g.*, of the clovers and rye-grasses) in the seeding year, and heavy hay crops in the first harvest year are adverse to successful establishment, and particularly is this so in respect of the slower growing species. The success of a seeds mixture, therefore, turns very largely on the manner in which the grazing is regulated from corn harvest to the date of " putting up " to hay.

Competitive Influences.

The more essential of the practical points which emerge from the evidence discussed in this bulletin are :—(1) The rye-grasses (especially Italian) and red clovers, if allowed to grow luxuriantly in the autumn (of the seeding year) are liable to exert a disastrous smothering effect on other species ; (2) the influence of Italian rye-grass will depend on the methods of grazing adopted during the autumn, winter, and spring ; any harmful influence can be reduced to relatively slight significance when fields are " put up " to hay late—the rye-grass then providing valuable spring grazing and acting rather as a protection to the later grasses than the reverse ; (3) " pasture mixtures " consisting predominantly of " bottom " grasses and wild white clover are assured of the greatest success when competition (by shading) is reduced to a minimum—that is to say, when they are grazed on a proper intermittent basis from the very outset and when hay is never taken ; (4) under hay conditions (especially when early " put up ") competition (by shading) is at its maximum, and consequently to sow any species whatsoever in small amount with other species in large amount is to waste seed and to spell an ill-balanced mixture. Particularly inept are large seedings of rye-grasses with small seedings of timothy, cocksfoot, meadow fescue, and the like. The blending of many species each capable of doing the same thing is of course to make it impossible for each of the species so blended to perform its intended part. It is perhaps a just irony of fate that when large quantities of the cheaper species are sown with small quantities of the more expensive it is the cheaper species (the rye-grasses) which gain the early mastery, and largely render the half-hearted inclusion of the more expensive species a waste of money pure and simple.

The Balance of the Sward.

In the present connection " balance " will chiefly be considered from the palatability and ration point of view, the " seasonal " and competitive aspects of balance having already been dealt with. Recent chemical evidence strongly suggests that as far as albuminoid ratio is concerned " balance " can be largely left to look after itself—the differences in protein content between the different eatable species not being of great significance except in so far as a high clover-grass ratio betokens a high albuminoid ratio, and this, it should be emphasized, not only in the hay but, although to a lesser extent, even in the case of well grazed pasture grass. We now know, however, that balance should also take consideration of the mineral content of the herbage, and in this regard the species do vary very appreciably one from the other—and at all stages of growth. The clovers are much richer in silica-free ash (and that is what matters) than are the grasses. Now the clovers make negligible winter and early spring growth.

Certain herbs, notably chicory, are rich in silica-free ash, and many of these provide important leafage during the winter, and in consequence are probably to be regarded as very valuable herbage plants—particularly on soils deficient in essential minerals. It is perhaps not without significance that the bent grasses so abundant on soils deficient in lime and phosphates are poor in both ingredients, while red fescue is rich in lime, and cocksfoot rich in phosphates. The significance lies in the fact that indigenous strains of the two latter species have shown themselves propense to bent-dominated soils.

Balance in relation to palatability is an interesting subject upon which to speculate—" the more varied the species, the more subtle the shades of taste, and therefore the greater the zest to ravenous eating " is a tacit assumption freely made. It is possible, of course, that a mouthful here and there of a highly flavoured grass like sweet vernal grass may have an inspiring influence on the " will to eat " of the animal, and that scattered plants of such a species may conceivably have an immense value on the sward.

It is equally possible, and indeed much more likely, that animals long confined to herbage consisting of a single species or of but very few species may tire of the taste of the same diet day after day. It is probable too that some species (*e.g.*, perennial rye-grass) are less objected to (if indeed objected to at all) as a predominant food than others. The behaviour of animals on pastures of a restricted flora (*e.g.*, many of the fatting pastures, or on pure plots of Italian rye-grass) does not, however, suggest that " reluctance to eat " luxuriant herbage consisting of unimpeachable herbage plants, because of a sort of nausea consequent upon the craving for a new taste, is a phenomenon that often exhibits itself in healthy animals grazing a healthy sward. There is no evidence that balance from this point of view should necessarily cater for a herbage consisting of a dozen or more first-class herbage species—or that a simple mixture of three or four palatable species is on this account inadequate. It must be remembered that no sward will be devoid of weeds, and further that under any reasonable system of intermittent (=rotational) grazing, animals will necessarily be moving from sward to sward (from ration to ration). It is a fact, however, that if small plots of different mixtures or of different pure species are set out in the middle of a field sown down with a single simple mixture, some at least of such small plots generally receive exaggerated attention from the animals. This perhaps suggests that the animals like (but on that account do not necessarily demand) a measure of variation in their daily diet—a measure of variation which if indeed necessary can of course perfectly easily be safeguarded by sowing a few " different " strips across any field put away with a sensible simple mixture. The fear of nausea is not, therefore, an argument of much force to be levelled against the simple mixture, since those who are nervous in this connection have such an easy method of allaying their fears, and of acquiring interesting information as to the habits of animals and the behaviour of seeds mixtures into the bargain.

The Response to Management.

For many purposes and in many hands it is important that a herbage species should be " fool-proof," that is to say, that it will not lead to the deterioration of the sward under conditions of management not well suited to it, and further, that from the point of view of producing palatable herbage it may continue to do so despite maltreatment. Perennial rye-grass, rough-stalked

meadow grass, and wild white clover when fully established on a sward are wonderfully " fool-proof " from all points of view. Crested dogstail requires a limited amount of attention—the flowering stalks should be run over with the mowing machine. Italian rye-grass to be kept productive as a pasture grass should not be grazed continuously, but intermittently. Cocksfoot is very far from " fool-proof," and unless grazed hard on an intermittent basis will soon grow out of its palatable condition and become tufted—when waste will ensue and actual harm will be done to the finer grasses. The same is true of Yorkshire fog and to a marked degree of the bent grasses, while the red clovers, particularly late flowering red clover, at midsummer, if not sufficiently grazed, may exercise an adverse influence on other species in the sward. A species that is not " fool-proof " should not be included in a mixture, unless there are reasonable grounds for supposing that the resulting sward will receive the skilled attention demanded by luxuriant but otherwise not wholly blameless species.

The Compounding of Seeds Mixtures.

Swards intended for three or more years duration only will be considered and attention will be concentrated on " purpose." The mixtures here given are only necessarily applicable to the higher rainfall regions of Britain, since they are all based on results actually obtained in Wales in districts with a rainfall usually exceeding 35 inches per annum.

Grazing-only Mixtures.

The mixtures here discussed are intended for grazing only, and it is assumed that they will be grazed within 8 to 12 weeks after sowing.

Hay crops can of course be taken in the first harvest year, but this is not recommended, and in any event the crop should only be allowed to be a light one. The mixtures here advocated are exceedingly simple and are equally suitable for 3—4 year leys or for permanent pasture. They are essentially bottom grass mixtures.

In its simplest form a grazing mixture may be as under (lb. per acre) :—

Italian rye-grass	8 lb.
Perennial rye-grass	14 lb.
Rough-stalked meadow grass	4—6 lb.
Wild white clover	2—3 lb.

It is highly desirable that the perennial rye-grass should be indigenous (*ex* wild white clover). Such a mixture can advantageously be sown with about 6 lb. of rape.

Essential modifications may be made by substituting in whole or in part crested dogstail for rough-stalked meadow grass, or in extreme cases (conditions of the lowest possible fertility) using Chewing's fescue as the substitute. In no case should the place taken by one or other of these species, singly or the sum of two or three of them, be less than 4 lb., while the amount may often be increased up to 10 lb. with considerable advantage.

The only other point that arises is the question of additions, and expense will usually be a dominant consideration. At present there are probably only three species worthy of serious consideration as additions, and these are cocksfoot, chicory, and late flowering red clover—not one of which is " fool-proof."*

* Evidence discussed in the previous articles suggests that pedigree indigenous strains of timothy are likely to prove of immense value for inclusion in grazing mixtures—while under conditions of poor fertility it is likely that wild red clover (a good strain) will come to have considerable importance.

An extra late red clover (*e.g.*, Montgomery late or Cornish marl) will add enormously to the summer grazing in the first and second harvest years, but as before said if not converted harm to the sward will result, and money spent not only on the red clover but also on the bottom grasses and wild white clover will have been largely wasted—or as frequently happens in practice the seed of the bottom grasses and wild white clover will have been skimped in order to pay for the less important red clover. It is as well to remember that the price of 3—4 lb. of late red clover will usually purchase 1 lb. of wild white clover.

Ordinary Danish cocksfoot—like the late red clover—will add to the grazing in the first two years, but it is even less " fool-proof," and should never be included.

Quite different is the case with wild or indigenous cocksfoot or with reliable New Zealand—these are not " fool-proof," but should hold the sward for many years, and under worthy management will repay inclusion, especially on land lower in the scale of fertility than first class. If included, what sort of a relationship should the cocksfoot bear to the rye-grass ? At high elevations there is considerable evidence to suggest that 14 to 18 lb. of indigenous or New Zealand cocksfoot might wholly replace the rye-grass—a safe sowing normally would be about 9 lb. of each species.

Chicory provides useful winter and spring grazing and is of high mineral content : provided the grazing will be hard, 4—6 lb. would be sound but expensive.

Mixtures of the extreme simplicity of the type given above have been extensively tested in the counties affiliated to the College ; many are now in their third harvest year, and the results have been uniformly good. The results have been outstanding in respect of winter greenness and in respect of providing winter keep. It is essential that the " wild white clover " should be wild white, and the perennial rye-grass *ex* old-sward, also that the rough-stalked meadow grass or its appropriate substitute should be sown with a generous hand,—these are the things that matter.

Grazing-Hay Mixtures.

Under this heading will be discussed leys which it is intended to graze till the end of April or even into May each year, that is to say, which will be " put up " late, and from which a light " herby " hay crop will be taken, and upon which rational, intermittent grazing will be adopted on the aftermath and throughout the winter. The case for the adoption of such a practice as this is founded on the soundest of principles. Firstly, early spring grazing (that most essential commodity) is more abundant on fields previously yielding hay than on those previously wholly grazed. Secondly, the persistency of the higher yielding strains is favoured by the plants being allowed a period for full development (*i.e.*, the hay producing period). Thirdly, the hay will be leafy and nutritious with a high clover content. Fourthly, the competitive interaction between the plants can be so regulated as to turn the behaviour of the contributing species to the maximum of economic benefit. Two points of management should be mentioned in connection with this method of grassland husbandry. The productivity will be high, very high under a system of generous manuring which should be complete and include nitrogenous fertilizers. The point in this connection is the question of the best time at which to apply a single nitrogenous dressing. The correct time is the autumn—that is to say, after, and not before, the hay producing period. Farmyard manure, for example, applied in the

autumn (while growth is still active) greatly favours continued growth and winter-greenness, and makes for an early and good start in the spring. Root development is at a maximum after the hay producing period, and consequently the plants are then in an ideal condition to utilise plant food, and will consequently pass into the winter in a healthy and well-fed condition, with results that will be splendidly apparent during just those months when grazing is most scarce and most needed. The second point is connected with hay making : since the crop will be leafy and " herby " it will be difficult to make, but on the other hand it will not be heavy, and consequently, unless the weather conditions are entirely unfavourable, such crops are generally manageable.

A Suitable Mixture.

Mixtures for the purpose under review can be, and should be, reasonably complicated—the whole aim being to combine early species and strains with late species and strains, the former to provide early spring grazing, and the latter to produce the hay crop and to contribute again to the autumn and winter pasturage. The aim here is to achieve a sort of time balance, and this can largely be accomplished not only by blending different species (the early and the late) but also by blending different strains of the same species. Since, moreover, any particular set of conditions does not favour a large number of species, it is usually rather by an informed blending of strains than by an indiscriminate blending of species that the most sensible mixtures will be compounded.

The type of mixture to use would be somewhat as follows (in lb. per acre) :—

Italian rye-grass ..	.. ..	6
Perennial rye-grass :	Irish, Ayrshire or New Zealand	4
	Svalöf Victoria	4
	Ex wild white	7
Cocksfoot :	Danish	3
	New Zealand and (or) indigenous	7
Timothy :	American or Ayrshire	2
	Svalöf Gloria	3
	and indigenous	3
Rough-stalked meadow grass :	Danish	2
Crested dogstail :	Irish or New Zealand	2
Broad red clover :	English or New Zealand	2
Late flowering red clover :	Montgomery or Cornish marl	3
	English late (*e.g.*, Essex)	2
White clover :	European	1
	New Zealand	1
	Wild white	1

NOTES.—A high seed rate is unavoidable since if a strain is worth including the amount of seed must be adequate—while in any event rapid establishment is assisted by a generous seed rate : furthermore, it is intended that the sward should be well grazed even in the first autumn and spring. The rough-stalked meadow grass and crested dogstail can be regarded as interchangeable, but the seeding of one or other or both of these regarded as a unit should not be less than 4 lb. Evidence suggests that indigenous meadow foxtail would also be a valuable addition to such mixtures, but at present the seed of this strain is not a commercial commodity. The use of such early grasses as tall oat grass, tall fescue, and golden oat grass are ruled out because the first will not long withstand the heavy early grazing, the tall fescue is not highly palatable, and the seed of the golden oat grass is altogether too expensive.

Should the above mixture seem too expensive, economy should be effected by deleting certain strains altogether, rather than by a wholesale reduction of the seed-rate all through. The strains that could be discarded without influencing the resulting sward too seriously would be the Danish cocksfoot, the American or Ayrshire timothy, the broad red clover, and the European white clover.

Hay-then-Pasture Mixtures.

As before stated the most usual demand made on a mixture is to provide one or two harvest years of hay followed by two, three or four years of grazing. For such purposes mixtures of extravagant complexity may still be seen to grace the pages of the catalogue of some of the seed houses, but the type of mixture that has come into most general use is that advocated by the late Professor Gilchrist and which has come to be known as the standard Cockle Park mixture. From the point of view of the grazing year, this mixture as often employed suffers from a serious defect, namely, the total exclusion of rough-stalked meadow grass or crested dogstail. In regions of high rainfall and on lime deficient soils trefoil does not succeed and is therefore not a telling ingredient, while the case for including alsike clover (although it often does justify itself) is not a very strong one.

The Cockle Park mixture does not cater for autumn and spring grazing immediately following sowing ; this is, however, a very common practice in many districts where the mixture is extensively employed and consequently the inclusion of Italian rye-grass is frequently called for. The Cockle Park mixture modified as hereunder has been largely recommended by the present writers, and has given uniformly good results over a wide range of conditions in Wales.

Modified Cockle Park mixture in lb. per acre :

Italian rye-grass	6
Perennial rye-grass	14
Cocksfoot	8
Timothy	5
Rough-stalked meadow grass and (or) crested dogstail	3
Late flowering red clover	6
Wild white clover	1—2

NOTES.

As in the mixture previously discussed there is here also much to be said for a blending of strains, particularly in the case of the perennial rye-grass and cocksfoot, as the late Professor Gilchrist himself proved, the New Zealand strain of cocksfoot, for example, being a highly desirable inclusion. In many districts the Montgomery or Cornish marl extra lates are the best red clovers to use. The ordinary commercial timothy frequently does not justify itself, and may often be excluded without materially influencing the result—it would then be wisest to increase the seed rate of the cocksfoot.*

The above modified " Cockle Park " does not exhaust the possibilities of the hay-then-pasture mixture, but it is beyond the scope of the present paper to discuss mixtures suitable for special or exceptional conditions.

Hay Mixtures.

An extended adoption of the practice of sowing fields down to grazing-only and (or) to grazing-hay mixtures would of course tend to reduce the amount of the hay crop, and would necessitate therefore the sowing of certain (and well chosen) fields to provide primarily for heavy crops of hay year after year. There is little doubt that the Scotch timothy-meadow represents exceedingly sound practice. In this case the mixture is primarily intended to cater for hay —the management being subservient to the production of a bulky crop. The fields are " put up " early and are frequently cut late—competitive influences between the species are therefore permitted to attain their maximum effect. Heavy crops are also demanded year after year as long as the ley will hold. In drawing up mixtures heavy manuring should be postulated, which will favour such species as are high fertility demanders.

* It is probable, however, that the best indigenous strains of timothy will always be worthy of inclusion.

Owing to their competitive influences both rye-grasses are better excluded from such mixtures—the hay species from which to select being tall oat grass, timothy, cocksfoot, and meadow fescue with late flowering red clover.

With the heavy production of hay year after year it is difficult to retain a good bottom to the sward—under conditions of high fertility the most promising species for this purpose is rough-stalked meadow grass (which itself contributes very appreciably to the hay), a species which should therefore always be included in generous amount in such mixtures. Although the conditions will be far from ideal for wild white clover, experience suggests that on the balance it is profitable to include this "weed excluder" to assist rough-stalked meadow grass in its essential function of developing a good bottom to the sward.

Type Mixtures.

The chief question to be decided is whether one or more of the large hay grasses should be included in these mixtures. With the rye-grasses excluded, cocksfoot is to be regarded as the aggressor species from those amongst which a choice is to be made, but this grass will not permit of the full development of either timothy or meadow fescue, so that with a proper knowledge of the conditions it is often best to rely upon a single hay grass. The following mixtures may be regarded as representative (in lb. per acre) :—

	Timothy (fertile conditions, damp or peaty soils)	16
or	Meadow fescue (fertile conditions) deep, rich loams	18
or	Cocksfoot (the widest range of conditions)	16
or	Tall oat grass (dry situations)	20
	Rough-stalked meadow grass (higher fertility)	4
or	Crested dogstail (lower fertility)	4
	Late flowering red clover	6
	Wild white clover	1—2

If it is desired to employ two of the hay grasses, tall oat grass and cocksfoot may be combined for the drier and less fertile conditions at the rate of about 9—12 lb. each ; while timothy and meadow fescue may together contribute to mixtures for richer and damper soils at the rate of about 9 lb. each. If three or four species are combined, the seed rate for each should be high, so that the conditions may have every opportunity of "selecting" and "retaining" a sufficiency of the successful species ; seed rates of less than 6 lb. per species would be unlikely to be effective, while 10 lb. per species, although apparently extravagant, would be perfectly sensible, if indeed the inclusion of the four species could under any circumstances be regarded as sensible.

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